Division of Agricultural Sciences

UNIVERSITY OF CALIFORNIA

ECONOMICS OF ON-FARM IRRIGATION WATER AVAILABILITY AND COSTS, AND RELATED FARM ADJUSTMENTS

1. Enterprise Choices, Resource Allocations, and Earnings on 640-Acre General Crop Farms on the San Joaquin Valley Eastside

Trimble R. Hedges and Charles V. Moore

CALIFORNIA AGRICULTURAL EXPERIMENT STATION
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FOREWORD

This report grew out of a broad study of on-farm irrigation under two California Agricultural Experiment Station Projects, Numbers 1641 and H-1863. The second of these is the California contributing project under Regional Research Project W-70, Economics of On-Farm Use of Irrigation Water. Titles of the California projects indicate their objectives and subject matter: Economics of Adjustments on California Cotton Farms, and Effects of On-Farm Irrigation Water Supplies and Costs on Cropping Systems and Production Adjustments. These analyses involved a great deal of data, some of which we drew from secondary sources; other parts of which represented primary data, although we may have obtained even this information through the cooperation of some other agency.

The present report is the first in a series under its general title. Others currently in preparation will have as subtitles, 2. Farm Size in Relation to Resource Use, Earnings and Adjustments on the San Joaquin Valley Eastside, 3. Some Aggregate Aspects of Demand for Irrigation Water and Production Response on the San Joaquin Valley Eastside, and 4. Subarea Variations in Relation to Resource Use, Earnings, and Adjustments in San Joaquin Valley Cotton Area. Another special report resulting from these same projects is Some Characteristics of Farm Irrigation Water Supplies in the San Joaquin Valley. Still additional material has appeared in California Agriculture and in various journals.

We are indebted to many agencies and individuals without whose generous cooperation neither this report nor others in the series would have been possible. Among these we can list only a few of those upon whom we relied most heavily. The major power companies serving the San Joaquin Valley, Pacific Gas and Electric, and Southern California Edison, authorized us to use well test data previously released to the United States Geological Survey. The latter agency aided greatly in this procedure by making photostatic copies from office records. The California Regional Water Pollution Control Board made well driller reports available to us (data for individual reports are not identified in order to keep both of these sets of information confidential). The California Department of Water Resources also assisted greatly in these studies by making maps, reports, and other information available, as did the United States Bureau of Reclamation. The California Irrigation Districts Association, many individual irrigation districts, and various manufacturers and distributors of irrigation pumps and equipment provided much valuable assistance in the form of factual data and interpretation. We, of course, drew heavily on published reports and releases of the agencies named here, plus many others.

Among the many individuals to whom we owe appreciation, we wish to mention particularly Messrs. R. S. Ayers, Wm. Balch, D. E. Butler, J. S. Gorlinski, E. J. Griffith, H. H. Holley, G. V. Hufford, J. M. Ingles, F. Munz, B. M. Smith, H. M. Stafford, S. T. Stairs, L. Stennett, and H. D. Wilson. A complete list would extend to a much greater length; we stop at this point only because of space limitations, not for lack of awareness or appreciation of the assistance generously made available by many others.

As indicated above, this report resulted from studies under two Experiment Station projects. The University of California Water Resources Center contributed an important fraction of the funds used in financing these studies, through its grants for research under Project H-1863. Regional support also was available under Project W-70.

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SUMMARY

Ample supplies of irrigation water at reasonable prices rank high among the critical requirements for profitable agriculture in California. Crops grown under irrigation regularly occupy 75 percent of the cropland harvested, and account for 90 percent or more of the aggregate value of all crops grown in the state. Many California farmers, due to rapid expansion in irrigation since World War II, now face present or potential shortages of water.

We made this study to determine in what ways variations in, first, quantities of irrigation water, and, second, water costs affect farm decisions and profits under conditions existing in the eastern San Joaquin Valley. This analysis also measures these effects as accurately as possible, according to price and other relationships during the period 1956 through 1960. It centers on a 640-acre farm model with 602 acres suitable for irrigation. Equipment lines, labor force, and farming practices are typical of the general crop farms in the San Joaquin Valley Eastside. We examined irrigation water problems under three cropping systems for this overall model: (A) including all usual alternative crops; (B) excluding cantaloups, and (C) excluding both cantaloups and sugar beets.

The amounts of soil moisture available to plants diminish as soil moisture tension increases; the latter, measured in atmospheres, rises as the amount of water in the root zone diminishes between field capacity (FC) and the permanent wilting percentage (PWP). These relationships provide the basis for estimating average growth and yield rates for each crop under each soil condition and irrigation practice, using inverted soil moisture depletion (release) curves to represent growth and yield rates. Our yield estimates, in turn, in combination with the calendar of operations, schedule of inputs, and costs, enabled us to calculate gross receipts, and net returns-over-variable expenses for each crop under each combination of soil and irrigation practices. Budgeting procedures, based on farm and farmer service agency interview data, provided this comparative information.

Linear programming and farm budget analysis are the two primary methods used in this study to identify and measure interrelationships. The linear programming problem involves 7 crops, 3 irrigation practices, and 20 constraints. The latter include acreages by soil grades, water available by time periods, and various formal or informal planting restrictions. Budget analysis was used

in determining enterprise gross receipts, costs, and net returns, as well as for calculating total farm fixed (overhead) costs.

Farm fixed costs, including all depreciation, interest on investments, and other general expenses for the 640-acre farm, total $64,000. We omitted this item from all preliminary net return calculations for the various enterprise combinations, inasmuch as fixed costs remain unvarying for the range of cropping and production variations studied. Fixed costs enter the analysis used to calculate total farm profits. This calculation comes after determining maximum net returns-over-variable expenses under alternative enterprise operating combinations and conditions.

Cotton occupies 5, cantaloups 4, and sugar beets 1, out of the top 10 places for enterprise rankings according to net returns-over-variable expenses for one acre on the 640-acre farm model in this study. These rankings involve 8 enterprises single- or double-cropped, 2 soil grades, and 3 irrigation treatments. Net returns per acre vary from $249.00 for cotton to $12.00 for barley. Sugar beets, in tenth place, show $134.00 per acre as net returns-over-variable expenses. Other crops, primarily alfalfa hay and feed grains, all return less than $100.00 per acre.

Under 1956-1960 conditions, farmers on 640-acre general crop farms, may expect total farm net returns to equal all fixed costs at $16.00, $11.00, and $10.00, respectively, per acre-foot for irrigation water variable expenses, depending on whether they follow A, B, or C cropping systems. Such total farm returns cover interest on farm investments, but allow no returns to operator's management or supervision. Cropping System A (including both cantaloups and sugar beets), with two high income alternative crops, is able to cover fixed costs under the highest variable costs for irrigation water. At zero prices for water, System A returns $108,400 or $44,000 more than fixed costs. These returns <u>drop</u> as water variable costs <u>rise</u> from zero to $16.00 per acre-foot (the breakeven level) at the rate of $2,755 per dollar of increase per acre-foot. Net returns-over-variable costs for Systems B and C also decline sharply as water costs increase from zero to the breakeven level; $2,840 and $2,800 per dollar of cost rise, respectively.

When irrigation water variable expenses remain constant at $3.00 per acre-foot, total farm net returns-over-variable costs increase with added quantities of water available until the total amounts reach approximately 2,800; 2,735;

and 2,760 acre-feet, respectively, for Systems A, B, and C. These net returns not considering fixed costs equal $64,000, the "breakeven" level, at slightly over 1,000 acre-feet for System A, and at approximately 1,250 acre-feet for the other two systems. At lesser quantities, the operator not only would earn nothing for his management effort; he also would fail to recover all his fixed costs.

The variations among crops in net returns-over-variable expenses per acre exert important effects on crop choices and resource allocations under water scarcity or high water cost conditions. Under System C, an operator should allocate the first 900 acre-feet of a scarce water supply to cotton; this quantity at zero price per acre-foot, would increase total farm net returns-over-variable expenses by an average of $59.00 per acre-foot. The next 390 feet would return $43.00 per acre-foot, if applied to blackeyed beans on Chino (Grade I) soil; following this second increment, the operator should allocate the first 380 acre-feet of any additional supplies to alfalfa hay grown on Chino soil. It should return him slightly more than $13.00 per foot, as would further additions also used for alfalfa, but on Traver (Grade II) soil.

Changing water costs also bear heavily on enterprise choice and resource allocation decisions. For System B, with water variable expenses varying from zero to approximately $30.00 per acre-foot, each of five different combinations of enterprises and their respective acreages permits the operator to obtain maximum profits (or hold losses to a minimum) within some interval along this water cost scale. Only one (from zero to almost $12.00 per acre-foot) would yield net returns-over-variable costs at a sufficiently high level to cover total farm fixed costs. Cotton dominates all five farm organizations in this analysis; it is profitable to operate all the Chino (Grade I) soil through the first four price increase intervals for water, and their associated variations in farm cropping organizations. At the highest cost level, however, ($25.50 to $32.00 per acre-foot) the optimum cropping organization leaves 61 acres of this best soil idle. Farmers who know these relationships should reduce quantities of water used as costs per acre-foot rise in order to obtain maximum profits (or hold losses to a minimum). The adjustments in acreage allocations represented by these five different optimum cropping organizations for System B under varying water prices indicate the nature of these shifts. Farmers use drier treatments, shift to lower water requirement-crops, leave some land idle, or finally, go entirely out of production.

Water shortages, or excessively high costs, sharply reduce total farm profits. At $3.36 per acre-foot for irrigation water, the operator on a System C farm (excluding cantaloups and sugar beets) would realize over $16,000 as pay for his managerial services and as reward for risking over one-half million dollars in the business. His management return would drop to $3,200 if water variable costs rise to $8.00 per acre-foot. Systems A and B, with other high-net-return crops in addition to cotton, would fare better than System C; net earnings at $8.00 per acre-foot water costs would still hold at nearly $19,000.

Inadequate water quantities also handicap farmers; reducing total water available to 1,616 acre-feet, with variable costs remaining at $3.00 per acre-foot, exerts about the same profit-depressing influence on the System C model as increasing water costs from $3.36 to $8.00 per acre-foot, with no reduction in quantity.

Price changes for the product representing the major income source can greatly influence gross receipts, farmer ability to pay for irrigation water, and profits. Cotton is the product holding such status on general crop farms in the San Joaquin Valley Eastside. We analyzed how cotton lint price variations might affect irrigated operations and profits, assuming the United States price supports and acreage allotments do not exist, and that farmers follow production policies that will return maximum profits.

Under such free market conditions, cotton will enter the cropping plan when lint prices reach about 18 cents per pound. Relatively small rises, up to about 21 or 22 cents per pound, will stimulate sharp acreage and production increases. Using System B (including sugar beets, but no cantaloups) we found that net returns-over-variable expenses reach the $64,000 breakeven level with cotton lint prices at 21.5 cents per pound. This assumes that irrigation water variable costs are $3.00 per acre-foot. Lint prices would need to reach 27.5 cents per pound, and cotton acreage about 400 acres (as compared with the 33 cents price and 200-acre allotment under the actual United States cotton program) for the 640-acre farm model to return as much profit under conditions of this study as price supports and allotments permitted in the late 1950's. Still higher lint prices, and greater production, are required if irrigation water variable costs rise above the assumed $3.00 level. Under conditions of this study, farmers could not afford to pay more than this $3.00 per acre-foot in irrigation water variable expenses, and remain in business, unless

(a) cotton lint sells for at least 21.5 cents per pound, and (b) they are free to plant up to 375 acres in cotton, and to produce about 800 bales. Any further cotton price gains above this level would return the grower a profit above total farm fixed costs; this revenue could make it possible for him to meet higher water costs.

ECONOMICS OF ON-FARM IRRIGATION WATER AVAILABILITY AND COSTS, AND RELATED FARM ADJUSTMENTS

1. Enterprise Choices, Resource Allocations, and Earnings on 640-Acre General Crop Farms in the San Joaquin Valley Eastside

Trimble R. Hedges and Charles V. Moore[1/]

THIS STUDY ANALYZES HOW VARIATIONS IN IRRIGATION WATER QUANTITIES OR COSTS AFFECT RESOURCE USE AND EARNINGS ON INDIVIDUAL FARMS

The broad objectives of this investigation are to establish and measure as accurately as possible the effects of variations in, first, farm irrigation water quantities, and, second, costs on relative profits from alternative crops and land uses; on optimum choices and resource allocations among crops; on total farm organization, production and profits. The analysis also must consider relevant economic and institutional factors, including costs for other resources and prices for products sold. In order to accomplish these over-all goals, specific objectives must be met; it is necessary to:

1. Construct input-output models for irrigation water use in crop production; including both annual totals and seasonal distribution patterns. These models must establish quantitative and temporal relationships between water inputs and product outputs or yields.

2. Establish the physical characteristics of farm irrigation water supplies, including both underground and surface sources; determine how such characteristics relate to costs; establish the cost components and structure for farm irrigation water, including both fixed and variable elements.

3. Construct a farm model that will typify modal characteristics for a specific farm organization and size under specified conditions, in order to identify and measure how varying water supply and cost conditions affect total farm performance and profits.

4. Construct complete input-output models for all production materials and services; determine total revenue, aggregate variable expenses, and net returns-over-variable expenses for each alternative crop; relate these basic facts to relevant resource, economic, and institutional conditions for the farm model.

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5. Identify economic choice criteria governing crop selection and resource allocations; develop effective measurement techniques for the purpose of maximizing enterprise and, ultimately, total farm net profits.

6. Establish the relationships between irrigation water supply and costs, and seasonal availability characteristics, on the one hand, and the critical resource use and earning features of the total farm business, on the other; consider the influence of varying supply and price conditions for other critical resources and for important farm products.

7. Explore the opportunities for adjusting the farm organization to variations in availability and cost of water, and to changes in other major institutional and economic forces affecting farm organization and earning.

Water Costs May Limit Decisions on Irrigated Farms

Total costs for irrigation water vary widely at any one time on California farms. This is true regardless of whether farmers pump water from underground, obtain it from agencies furnishing surface water, or rely on a combination of these sources. A recent analysis based on San Joaquin Valley conditions found that total farm pumping costs varied from as low as $2.40 to as high as $22.63 per acre-foot, depending upon pumping lift, plant efficiency, discharge per minute, and other factors.[1/] Similar cost variations can exist in surface water costs; another study in the same region indicated that irrigation district costs, including toll rates (variable costs) plus assessments (fixed costs) to farmers for irrigation water delivered to the farm head gate varied from a low of $1.14 per acre-foot for one district in a wet year to $9.33 for another during a dry year.[2/] Even wider variations are possible in the future; the possibilities for low cost water developments already have been exploited. Additional supplies of irrigation water, to be required for increased irrigation on both existing and newly-developed land, inevitably will come at higher costs than farmers now pay.

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1/ Moore, Charles V., and Trimble R. Hedges, "Irrigation Costs of Pumping in the San Joaquin Valley," California Agriculture, Vol. 14, No. 10, University of California, October 1960, pp. 3-4.

2/ Moore, Charles V., and Trimble R. Hedges, "Water Deliveries and Costs in the San Joaquin Valley Cotton Area," California Agriculture, Vol. 15, No. 3, March 1961, pp. 7-8.

Quantities of water that farmers apply vary widely according to crops, soils, climatic conditions, irrigation systems, and other factors. Survey data obtained in this study indicate that applications in the San Joaquin Valley may vary from as little as 18 acre-inches for barley to 60 inches or more for alfalfa hay; much of the irrigated land receives water at the rate of 36 to 48 inches per year. Cost variations such as those cited above have serious impacts on profit rankings and farmer choices among alternative crops. They also can exert important influence on net earnings and total farm profits. A farmer applying five acre-feet of water per acre to alfalfa hay, for example, would incur total water costs of $12.50 per acre at $2.50 per acre-foot, $50.00 if the cost rose to $10.00, and $75.00 if it reached $15.00. Such input cost variations for this and other crops present farmers with critical decision situations.

Not only is the total cost important in irrigation decisions; the proportion of costs that are fixed and that are variable also frequently has important influence. Power charges dominate variable expenses in pumping from underground sources, with various overhead items on wells and plants as fixed costs. Similarly, delivery charges according to a quantity unit represent variable outlays for surface water; charges for amortizing and maintaining water agency facilities, usually assessed on a per acre basis, make up the fixed costs. Farmers must consider all these costs and their relative size when they make irrigation decisions. An important fact in such considerations is that fixed costs, once incurred, continue regardless of how much water deliveries vary.

PHYSICAL, INSTITUTIONAL, AND ECONOMIC DETERMINANTS ESTABLISH THE DECISION FRAMEWORK FOR IRRIGATED FARMS IN TULARE COUNTY

Land and Soil Characteristics Define Production Potentials for Irrigated Farms

Tulare County in the southeastern segment of the San Joaquin Valley and associated mountainous drainage areas, includes the area covered by this study (see Figure 1). We are concerned in the analysis with the valley land, and, specifically, with the farms occupying its irrigated portions. For 1960 total irrigated land is estimated at 627.7 thousand acres; this area produced crops with a market value of $221.4 million.

Tulare County includes sizeable acreages of highly productive soils among its irrigated alluvial valley land. Soil surveys for Pixley and Visalia areas indicate that 38 percent of the 1.2 million acre total classes as Grades I and II according to the Storie Index.1/ These soils are highly suitable for intensive farming under irrigation; they have the capacity to use large quantities of irrigation water, fertilizer, labor, power, and other inputs, and to return high yields of the principal adapted field and fruit crops. Grade III soils, representing another 38 percent of the total, also lend themselves to irrigation, although their range of crop adaption is somewhat narrower, and their yields lower than those for the two higher quality soil grades.

Climatic Conditions Make Irrigation Essential for Profitable Farming, but Otherwise Favor High Production

Low annual precipitation, virtually all of which occurs during the months of October through April, coupled with hot summers, limit nonirrigated crop production to barley, oats, and wheat for grain or hay (see Figure 2). Even this production is uncertain and characterized by low yields under the best conditions. Fallow rotations help lessen uncertainty, but cannot assure farmers of economic yields. Mean annual precipitation averages 9.5 inches in the irrigated areas of Tulare County.2/ Seldom does the total during the months of May through September equal as much as one inch!

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1/ Caton, Douglas D., Trimble R. Hedges, and W. Neill Schaller, Inputs and Costs for Producing Field Crops, 3. San Joaquin Valley Eastside Cotton Farms, 1953-1955, University of California, Agr. Expt. Sta., Giannini Foundation Mimeo. Rept. No. 203, May 1958, p. 2.

2/ Caton, Douglas D., Trimble R. Hedges, and W. Neill Schaller, Farm Adjustments and Earnings Under 1955 Cotton Acreage Allotments 3. San Joaquin Valley Eastside Cotton Farms, 1953-1955. University of California, Agr. Expt. Sta., Giannini Foundation Mimeo. Rept. No. 202, May 1958, pp. 9-10.

FIGURE 1. STUDY AREA AND PUMP LIFTS, SAN JOAQUIN VALLEY.

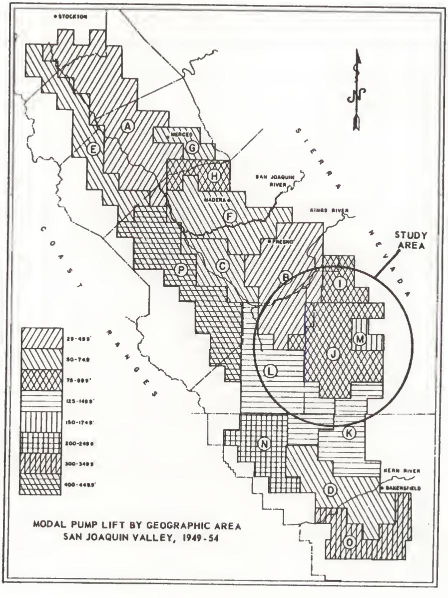
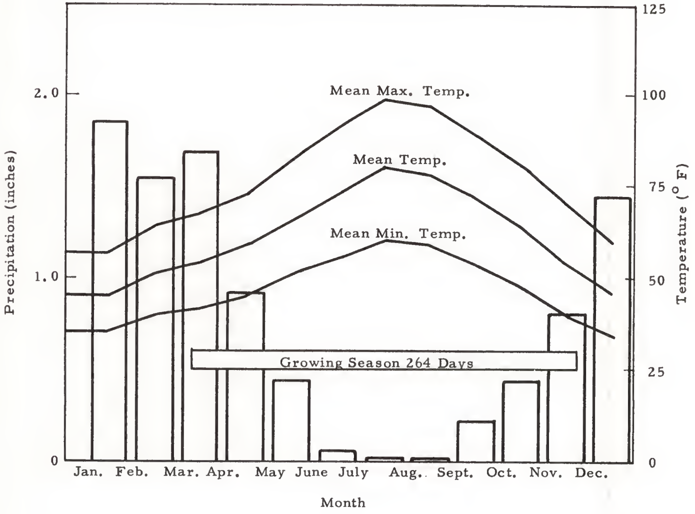


FIGURE 2. PRECIPITATION, TEMPERATURES, AND GROWING SEASON; VISALIA 1/



1/ Sources: Climatological Data, U. S. Weather Bureau; Period Averages: Precipitation - 58 years; Temperatures - mean 46 years, maximum & minimum 33 years.

Other climatic characteristics in the eastern San Joaquin Valley (Eastside) are highly favorable for crop production; they permit farmers to choose from among a wide range of alternatives, and to obtain relatively high yields under effective management. Growing seasons exceed 250 days throughout the irrigated portions of Tulare County, while mean temperatures are in the eighties during July. Winter temperatures seldom drop below freezing and usually average in the mid-forties during January (see Figure 2).

Seasonal Shortages of Irrigation Water Occur on Many Farms; These Are Aggravated During Years of Low Annual Precipitation

Farmers in Tulare County depend heavily on underground water pumped by their own plants. Many also use surface water for supplementary irrigation; some depend almost entirely on this source, particularly since the Bureau of Reclamation has completed the Friant-Kern Canal, and established regular water deliveries. Water tables had fallen extensively in the county, particularly in certain areas, before Friant-Kern water became available. Surface water supplies available from irrigation districts and other agencies were inadequate to prevent the groundwater overdrafts that led to lowering water tables.[1/] Operators on many farms continue to be short of water for irrigation during the higher-use months, either from reduced pumping discharge rates accompanying seasonal drawdowns, inadequate supplies of surface water, or a combination of both limitations. Such shortages usually worsen in low precipitation years and become quite acute if two or more such years occur consecutively. Under these conditions, further expansion in irrigated acreages for Tulare County must bring increasing water shortage problems.

Supplies of Other Resources and Market Outlets Are Generally Favorable

Both farm supply and marketing agencies and facilities in Tulare County are adequate for practically all requirements under existing production patterns. Local labor supplies represent one important exception; farmers depend on outside seasonal workers for much of the hand weeding and hoeing, and for a sizeable segment of the labor requirements in harvesting. Mechanization in the cotton harvest (93 percent machine-picked in 1961) and in other operations has reduced the seriousness of this shortage; migrant American workers and foreign nationals jointly supplement resident seasonal workers and meet farm needs.

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1/ State of California, Department of Water Resources, Ground Water Conditions in Central and Northern California, 1957-58, Bul. No. 77-58, Table 5, Sacramento, California, 1959, p. 87.

Cotton acreage allotments, proportionate shares in sugar beets, and the necessity to obtain a marketing contract for many of the specialty crops do impose constraints on individual farmer decisions in allocating land and other resources. Capital shortages, likewise, limit some farmers in their freedom to choose among alternative lines of production, and to allocate their other resources. Price support policies and levels, finally, exert highly important influences on gross receipts, net returns, and farmer decisions for any particular year. Thus California farmers accounted for a large fraction of the total increase in United States cotton acreage accompanying the Plan A-B option in 1959 and 1960. Our procedure in this analysis recognizes these several forces, and undertakes to evaluate their influence.

A 640-ACRE GENERAL CROP OPERATION WITH CHARACTERISTICS TYPICAL OF TULARE COUNTY IS THE BASIS FOR THIS ANALYSIS

Farmers and Service Agencies, Both Public and Private, Supplied the Data on Resources, Organizational and Operational Characteristics

Test results for 11,000 wells covering a five-year period were available for this analysis through the courtesy of the electric power companies and the United States Geological Survey under proper arrangements for safe-guarding the privacy of data for individual operations. Similar arrangements also made available the driller's reports for 800 wells drilled and developed during the same period. It proved possible by using these data, plus appropriate information on pump and motor characterictics as supplied by irrigation pump companies, to establish reasonably definite operational and cost characteristics for wells and pumping plants in the southern San Joaquin Valley.1/

Official reports and various officials and researchers in the State Department of Water Resources supplied detailed information regarding groundwater conditions, over-all use, and the relationships between precipitation and run-off on the one hand, and surface water availability on the other. We drew on irrigation district and Bureau of Reclamation reports to obtain water delivery and cost information for irrigation districts and other water agencies.

Soil survey reports were available for the Pixley and Visalia areas. These reports furnished soil classifications, major characteristics of each series-type, and inventories of the acreages in the more important grades. This information became the basis for our analysis of soil-water-plant relationships and yields for each crop. Weather data also came from official reports; these were essential in analyzing irrigation requirements.

Evapo-transpiration and soil water-holding capacity data were particularly important to this analysis; we obtained all available information through the cooperation of researchers in the soil-water-plant relationships area. Fundamental research in this field has progressed to the extent that some important quantitative results are available from experimental work. These results are not extensive enough, however, to provide all detailed and complete quantitative data needed for the crops, soils, and climatic conditions included in this study. We used estimates to compensate for such lacks, basing them on

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1/ Moore and Hedges, op. cit., Vol. 14, Nos. 8 and 10, Vol. 15, No. 3, p. 3 and 4.

experimental data that were available, plus the suggestions and judgment of soil-water-plant relationships researchers.

Interviews with farmers, machinery dealers and other farm supply agencies, agricultural researchers, extension specialists, and farm advisors provided the basic data on farm organization, resource availability and use patterns, production technology, practices, and inputs, and the general cost structure. Through cooperation of the Agricultural Stabilization and Conservation Committees at county and state levels it was possible to use their grower lists for drawing a sample of operators in the 600-to 700-acre size group. The procedure included interviews with 40 growers and an equal number of dealers and service agency representatives, both public and private. In addition, much information from earlier research and extension activity in the same area proved useful in this study, either to supplement, verify, or interpret the interview data.

Historical records and official reports, as well as interviews, contributed price and cost data. These were necessary to establish the price framework for analyzing how varying quantities and costs for water, other major inputs, and cotton selling prices would affect optimum resource allocation and returns. United States Department of Agriculture and California Crop and Livestock Reporting Service records and reports were valuable sources for these data.

The Farm Model Represents a Synthesis of Modal Characteristics in the Study Area 1/

Soils and acreages of each in the farm model represent both the relatively heavy and the lighter soils in Tulare County. Chino clay loam, Grade I under the Storie Index, is the heavier series-type while Traver fine sandy loam, classes

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1/ Major terms relating to farm models appearing in this report, and their definitions, are as follows:

Cropping System - detailed cropping organization for a Farm Model.

Farm Model - synthesized Farming System, based on modal farm characteristic date for a particular geographic subarea.

Farming System - Detailed organization, methods of operation, and practices used on a Farm Model (see Appendix Tables B-1, B-2, and C-1).

Subarea - a segment of a major geographic area, such as the San Joaquin Valley, selected for study.

Irrigation Practice - technique or method used in irrigation, identified in this study by the depletion level for available soil moisture prior to irrigation.

Variable Expenses (Costs) - sum of annual cash operating expenses, plus unpaid family (operator's) labor (see Appendix Tables C-1, C-2). This item may appear as Variable Expenses (Costs) per Acre for a single crop, or as Farm Variable Expenses (Costs) representing the total for an entire farm.

(Continued)

as Grade II, represents the lighter group. Acres, major uses, and percentages that each soil series-type represents of all farm land, are as follows:

Soils	All Land acres	All Land percent	Irrigable Land acres	Irrigable Land percent	Farmstead, Roads acres	Farmstead, Roads percent
Chino clay loam	448	70	421	65.8	27	4.2
Traver f.s.l.	192	30	181	28.3	11	1.7
TOTAL	640	100	602	94.1	38	5.9

It was not feasible to include each soil series-type occurring in the study area when developing the model for analysis; the ones chosen apply, however, to a range of similar soils within the respective grades. Thus the Chino series resembles the Tulare series of western Tulare County in texture and productivity.

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1/ (Continued)

Fixed Costs - sum of annual cash and noncash costs for using capital items and for general costs not readily allocated to specific enterprizes (see Appendix Table A-3).

Gross Receipts - sum of annual receipts from sales of farm crops.

Net Returns-Over-Variable Expenses (Costs) - Gross Receipts minus Variable Expenses. (Costs) (see Appendix Tables C-3 and C-4). This item may appear as Net Returns-Over-Variable Expenses (Costs) for a single crop acre, or as Farm Net Returns-Over-Variable Expenses (Costs) representing the total for an entire farm.

Net Farm Income - Net Cash income plus (or minus) inventory changes on noncapital items and minus noncash fixed costs (not including interest on investment). Any unpaid labor contributed by the farm operator is not included in the farm expenses.

Profit (Capital and Management Income)- Net Farm Income minus the value of any unpaid labor (including operator's).

Management Income - Profit less six percent on the total farm capital. The residual (and it may well be negative) is payment for the operator's managerial ability and services.

Rate Earned - Profit (Capital and Management Income) expressed as a percentage of the farm capital.

Irrigation facilities and water supplies for the farm model are consistent with these established by the analysis of ground-water conditions, well characteristics and pumping costs, and surface water availability and costs as reported above. Major characteristics for deep well turbine pumping plants, adjusted for seasonal drawdown, are as indicated below:

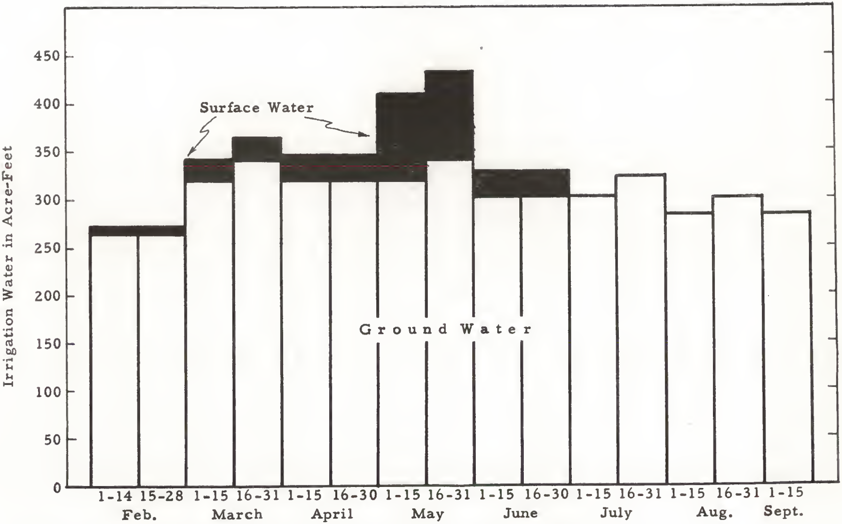
	1 March-31 May	1 June-31 July	1 Aug.-28 Feb.
		feet	
Total lift	127.4	132.4	137.4
G.P.M.	960.0	905.0	850.0
KWH per acre-foot	225.3	242.3	261.0
Over-all plant efficiency	57.9	55.9	53.9

Pumping facilities for the 640-acre model include five such wells, providing 18.87 acre-feet of irrigation water per 24-hour day in February, 21.33 for the next three months, 20.13 during the June-July period, and 18.87 in August and September. Surface water, diverted from unregulated stream flow, provides supplemental amounts; .58 acre-feet per day during February, 1.42 in March, 1.77 in April, 5.9 for May, and 1.79 during June. Total water available to the operator of this 640-acre farm with 602 acres irrigable thus varies from 18.87 acre-feet per day during the late summer months to a maximum of 27.23 in May when surface water is most plentiful (see Figure 3). Annual supplies for the February-September period include 4,586 acre-feet pumped from underground, plus 350 of surface water, or a total of 4,936 acre-feet.

Power and machinery inventories and investments heavily emphasize row crop production, but include hay mowing and raking machinery, and planting equipment for small grains (see Table 1). Farm operators commonly contract with custom operators for hay baling and grain harvesting.

Total fixed costs include noncash and cash overhead on farm property, plus general farm overhead (see Table 2). Land inventory values are not precise market or sales values; they reflect a combination of price-affecting forces, including tax assessments, basic physical productivity, and farm product values computed on a period normal basis. These estimates are valuable primarily for the purpose of suggesting the relationship of total farm earnings to farm capital investments, and for making comparisons among farm units of various sizes at later stages in the research project of which this analysis is a part. Farm life for structures and equipment,

FIGURE 3. IRRIGATION WATER SUPPLY 640-Acre Farm [1/]



1/ Assumes pumps operate 24 hours per day during Irrigation Season.

TABLE 1

Farm Real Estate and Operating Equipment Inventories and Investments; 640-Acre Crop Farm

Item	Size or capacity	Number	Useful life on farm	Initial cost	Salvage value	Average value
	1	2	3	4	5	6
			years	dollars		
Land						
Raw land	$500/acre	640 acres	--	320,000	0	320,000
Leveling	$100/acre		--	64,000	0	64,000
TOTAL	$600/acre		--	384,000	--	384,000
Improvements						
Tractor shed		1	30	1,250	0	625
Storage shed		2	30	4,000	0	2,000
Fuel storage (gas)	550 gal.	1	20	135	0	67
Fuel storage (diesel)	550 gal.	1	20	135	0	67
Shop equipment			10	1,000	0	500
Labor housing	2 bedroom	3	27	24,000	0	12,000
TOTALS				30,520		15,259
Irrigation						
Pumps	45 h.p.	5	20	23,845	2,530	13,187
Wells	678 ft.	5	15	48,830	0	24,415
Pipeline						
14 in.	14 in.	10,560 ft.	40	9,821	0	4,910
18 in.	18 in.	6,600 ft.	40	8,778	0	4,389
Stands	36 in.	8	40	452	0	276
Vents	5 in.	24	40	413	0	206
Alfalfa valves	14 in.	248	30	7,800	0	3,900
Syphons	2 in.	600	3	1,200	0	600
Irrigation (added)				16,316	580	8,448
TOTALS				117,435	3,110	60,331

(Continued on next page.)

Table 1 continued.

Item	Size or capacity	Number	Useful life on farm	Initial cost	Salvage value	Average value
	1	2	3	4	5	6
			years	dollars		
Power						
Tractor, tracked	70 h.p.	1	10	17,160	2,402	9,781
Tractor, wheel	35 h.p.	3	8	10,290	1,235	5,762
Tractor, wheel	25 h.p.	2	8	5,620	674	3,147
Transport						
Pickup	1/2 T	3	5	7,170	2,151	4,660
Truck	1 1/2 T	1	10	3,785	378	2,081
Trailer, equip.	--	1	15	500	0	250
Trailer, cotton	5 bale	6	10	3,600	0	1,800
Trailer, low-bed	--	1	15	500	0	250
Machinery						
Landplane	10 ft. x 40 ft.	1	20	2,700	0	1,350
Scraper	10 ft.	1	10	750	0	375
Ditcher	54 in.	1	20	400	0	200
Chisel	12 ft.	1	10	1,200	0	600
Subsoiler	2 shank	1	10	1,400	0	700
Plow, 2-way MB	2 x 16 in.	1	10	825	0	412
Disc harrow, OS	18 ft.	1	10	2,050	0	1,025
Disc harrow, OS	7 1/2 ft.	1	10	800	0	400
Lister	4 row	1	10	225	0	113
Cultipacker	20 ft.	1	15	875	0	437
Harrow, spike tooth	30 ft.	1	20	250	0	125
Disc, border		1	10	225	0	112
Planter	4 row	1	10	1,000	0	500
Cultivator	4 row	2	10	1,750	0	875
Stalk cutter	2 row	1	10	675	0	338
Cotton harvester	2 row	1	6	19,000	1,900	10,045
Grain drill	10 ft.	1	10	800	0	400
Mower	7 ft.	1	5	475	0	237
Rake	8 ft.	1	10	640	0	320
TOTALS				117,065	8,740	46,295
ALL PROPERTY TOTAL				649,020	11,850	505,885

TABLE 2

Summary of Fixed Costs
640-Acre Crop Farm

	Non cash fixed costs			Cash fixed costs				Total all fixed costs
	Interest on inv.	Depreciation	Total	Taxes	Insurance	Other	Total	
	1	2	3	4	5	6	7	8
Basis or assessment	Ave. value	Orig. costs		Assessment	Ave. value			
Rate or levy	6 percent	varies		$6.50/$100 or .02275 x ave. value	75 percent	varies		
	dollars							
Property								
Land 640A	23,040		23,040	6,240			6,240	29,280
Labor housing, 3	720	900	1,620	270	90		360	1,980
Other improvements	195	295	490	74	20		94	584
Irrigation, (original)	3,113	5,466	8,579	1,196			1,196	9,775
Irrigation, (added)	507	968	1,475	194			194	1,669
Machinery and equip.	2,777	9,404	12,181	1,054	620		1,674	13,855
TOTAL PROPERTY	30,352	17,033	47,385	9,028	730		9,758	57,143
General overhead								
Social Security and Workmen's Comp.						1,360	1,360	1,360
Office, accounts, and dues						800	800	800
Irrigation demand charges						1,497	1,497	1,497
Irrigation district assessments						3,200	3,200	3,200
TOTAL GENERAL	—	—	—	—	—	6,857	6,857	6,857
TOTALS	30,352	17,033	47,385	9,028	730	6,857	16,615	64,000

salvage values where used, prices and cost rates, and such items as assessments and levies for the Old Age and Survivor's Insurance under the Social Security System reflect existing or normal levels, based on official reports and interview data.

The farm labor force includes the portion of the operator's time not devoted to management and supervision, three full-time hourly wage employees (whose perquisites include free housing and utility services), plus part-time hourly-wage workers as required, and seasonally-contracted hand labor. Among the tasks included in the latter category are cotton chopping, sugar beet thinning, and similar nonmechanized production inputs.

Crops and acreages on 640-acre farms in the study area during the 1954-1960 period reflect applicable federal farm policies and regulations, established marketing arrangements and practices, and the price relationships among products, production inputs, and services. The simplest cropping plan usually includes at least three crops; these, by typical 1954-1958 acreages, were cotton, 260; alfalfa hay, 173; and barley, 132 acres. Such a cropping pattern leaves 37 out of the 602 acres in the total farm fallow or idle. Sugar beets, dry edible beans, and cantaloups are the more common among specialty crop choices, but potatoes, alfalfa seed, and sometimes others may enter the farm organization. Some farmers also grow other feed crops; among these are grain sorghum (milo), irrigated pasture, field corn, wheat, and grain hay. If prices, resource availability (e.g., quantities of irrigation water), institutional forces (e.g., acreage allotments), or other conditions change, crop choices and acreage and other resource allocations also may shift. It is the purpose of this study to determine in what direction and to what degree; we deal with these questions in the following sections.

Increased latitude for expanding cotton acres under the Plan A-B programs in 1959-1960 brought increases in cotton; some growers also planted other crops, and thus avoided leaving tillable acres idle or fallow, even during the years of normal government acreage allotments for cotton. Aggregate acreage data for the eastern San Joaquin Valley reflect these tendencies among operators on farms of all sizes to concentrate heavily on cotton, alfalfa hay, and barley. In spite of such tendencies, however, growers in this area allocate important acreages of land to various other field and specialty crops. Thus we include some of the more commonly grown specialty crops in our analysis; we consider

them in attempting to evaluate how variations in water availability and costs, as well as other resource and price conditions, affect optimum resource use and earnings. Such determinations may provide important suggestions as to how future changes may alter existing relationships among crops and resources.

Alternative Crops Vary Widely in Gross Receipts, Input Costs, and Net Returns Per Acre

Total fixed costs for the 640-acre farm amounted to $64,000 of which $57,000 represents costs related to land and other real estate items, or to farm power, machinery, and equipment (see Table 2). Much of the remaining $7,000 went for electric power demand charges and irrigation district assessments, both of which relate closely to resource use. Thus a relatively small amount of the total fixed costs represents such "overhead" items as Social Security taxes, dues, office expense, and other general costs.

Our analysis disregards these total farm fixed costs in the procedures directed to finding the optimum crop selections and the acreages of each that will maximize profits. These choices depend directly on output, product prices, total revenue, variable expenses, and the net excess of gross receipts over the latter item. We do consider fixed costs, however, in our total farm summaries and profit and loss statements. The latter earnings measures, calculated after determining what are optimum acreages under the conditions studied, and the associated net returns-over-variable expenses, are shown in a later section. It is possible thus to defer considering fixed costs because the over-all farm organization and the fixed costs structure show but little variation within the range of possible shifts in acreage allocations among the several alternative crops. This fact enables us to concentrate on the revenue, variable expenses, and net returns per acre from the several adapted enterprises, on their relative profitability, and how their profit levels and rankings shift under changing resource and price conditions.

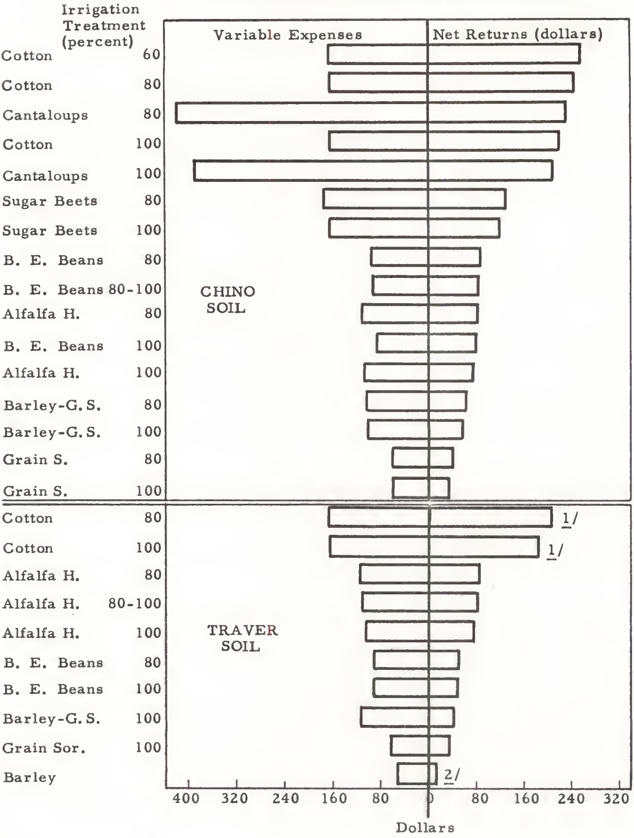
Our analysis directed to comparing crops according to net returns centered on the individual acre, the technical unit in crop production. Gross receipts (total revenue) per acre vary with output or yield, and with prices. This analysis considers such variations associated with yield differentials reflecting differences in soil quality and irrigation practices; we also undertake to

evaluate how changing prices for water and cotton affect costs, revenue, and net returns. Variable expenses include outlays for labor, fertilizer, seeds, pest control and other materials--fuel, electricity, repairs, custom services, and other direct inputs.

We used a budget analysis procedure to determine net returns-over-variable expenses per acre. The first step was to establish the typical calendar of operations and table of physical inputs and costs for each of nine crops selected as the most likely alternatives for production on the farm model under the conditions in the study area. Two sets of calculations were necessary; one with and one without the costs for irrigation water and associated inputs. Such variable production cost tables were prepared for each of three irrigation treatments applied, for most of the crops studied. Next we subtracted these variable production cost data for the several crops from gross receipts for each of the individual crops under the yields associated with each irrigation treatment. This procedure yielded an array of gross receipts, total variable expenses, and net returns-over-variable expenses for the nine crops considered. Two of these enterprises, field corn and alfalfa seed, clearly did not merit further consideration, on the basis of their total net returns and relative rankings, and were dropped from the analysis. This left seven crops, two of which, barley and grain sorghum, also occur again in a double-crop combination. Cotton on Grade I soil is the most profitable alternative for the farm model, irrigated under either the 60 or the 80 percent soil moisture depletion practice (see Figure 4). Cantaloups, also on Grade I soil and irrigated at the 80 percent soil moisture depletion ratio, are more profitable than cotton irrigated at 100 percent soil moisture depletion on the Grade I soil. Little difference exists as between cotton and cantaloups on Grade II soil, regardless of the irrigation practice, although the latter crop earns slightly higher net returns-over-variable expenses than cotton (see Appendix Table C-4).

It is evident that both soil quality and irrigation practice affect net returns, as well as, initially, both gross receipts and variable expenses. Further examples are evident among the other crops, according to soil qualities and irrigation practice. Still more would arise if we included additional soil qualities in the analysis.

FIGURE 4. NET RETURNS PER ACRE FOR SPECIFIED CROPS BY SOILS AND IRRIGATION TREATMENTS.
(percent depletion of available soil moisture)



1/ Cantaloups at 80; net returns $198, expenses $478, receipts $676: At 100; net returns $190, expenses $460, receipts $650.

2/ Barley for Chino; net returns $19, expenses $49, receipts $68.

METHODS USED WERE SELECTED TO MEASURE AND COORDINATE TECHNICAL AND ECONOMIC RELATIONSHIPS

Soil-Water-Plant Relationships are Basic to Output

Physical relationships among the soil, water, and plants critically affect plant growth and crop production. They regulate the extent to which water is available to meet plant needs, and therefore provide the basis for efficient irrigation practices. Two definitions are important in analyzing the more important of these relationships, field capacity (FC) and permanent wilting percentage (PWP). The first represents all the water that a particular soil will hold following a thorough wetting, and after allowing enough time thereafter for free water to drain out by gravity. PWP refers to the soil moisture content below which the plants cannot obtain water readily. Plants will wilt at this moisture level, and do not recover unless water is added to the soil.[1/] Questions regarding profitable irrigation practices, therefore, concern the amounts of water to be added, and their proper timing, in order to maintain soil moisture within the range between field capacity and PWP that will permit the level of net dollar returns to the operator that he seeks.

The analysis in this study is based on the concept that in general the relative rate of plant growth depends upon the mean soil moisture stress in the active root zone; that is, that the tension with which moisture adheres to the soil particles near the active roots regulates the amount of moisture available to the plant, and, hence, its growth rate.[2/] The greater this tension, the more closely the water adheres to the soil particles, and the more difficult it is for the plant to obtain the moisture to meet its needs. This stress,

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1/ Viehmeyer, F. J., and A. H. Hendrickson, Essentials of Irrigation and Cultivation of Orchards, University of California, Agr. Ext. 1950, pp. 4-9 (Circ. 50, Rev. 1950). Viehmeyer, F. J., and A. H. Hendrickson, The Effects of Soil Moisture on Deciduous Fruit Trees, Report of the Thirteenth International Horticultural Congress, 1952, Vol. 1, pp. 306-319. See also: Beringer, Christoph, An Economic Model for Determining the Production Function for Water in Agriculture, University of California Agr. Expt. Sta., Giannini Foundation Res. Rept. No. 240, 1961. This study includes a review of definitions and concepts relating to soil-water-plant relationships appearing in agronomic literature.

2/ Hagan, Robert H., Factors Affecting Soil Moisture-Plant Growth Relations. Report of the XIV International Horticultural Congress, Netherlands, 1955, p. 86.

in turn, varies directly with (a) the number of particles in a given volume of soil (e.g., one cubic foot) and the uniformity of their arrangement, (b) the osmotic effect of salts present, and (c) the depletion level of the available soil moisture. Clay (heavy) soils hold more moisture at field capacity than sandy (light) soils, but water adheres more tightly to the fine particles in the clays than to the coarser ones in sandy soils. As salt content increases, soil moisture tension tends to increase; it also rises as the amount reduces from field capacity in the direction of PWP.[1/]

Not all scientists fully accept the view of soil-water-plant relationships that we use in this analysis. Some researchers of long standing in the field hold that variations in soil moisture content between field capacity and PWP have little bearing on plant development and yield. Some among those who support the mean moisture stress concept, moreover, concede that brief periods of high stress can have an exaggerated impact upon plant growth. They hold, nonetheless, that the moisture-stress theory represents the best approximation for a wide range of crop under varying soil and climatic conditions.

Yield Estimates Reflect Mean Soil Moisture Availability Ratios

The mean soil moisture availability-stress theory is the basis for our analysis of how irrigation affects growth and yields and, ultimately, becomes one of the important variables regulating profits on the individual farm.[2/] We assumed, furthermore, that growth is a completely reliable indicator of yield; that any given departure of growth rate from the maximum potential is accompanied by a yield reduction in the same proportion. The starting point for estimating yields associated with each irrigation practice was to obtain estimates for potential yields under optimum soil moisture conditions from researchers and specialists working on irrigation technology. The subsequent procedure involved six steps for the crops studied on each soil series-type, according to a given set of climatic conditions:

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1/ Wadleigh, Cecil.H., "Soil Moisture in Relation to Plant Growth," USDA Yearbook of Agriculture, 1955, Washington 25, D. C., pp. 358-361.

2/ Moore, Charles V., "A General Analytical Framework for Estimating the Production Function for Crops Using Irrigation Water," Journal of Farm Economics, Vol. XLIII, Part 1, No. 4, Nov. 1961, pp. 876-888.

1. Determining amounts of water, days between each successive pair of irrigations (length of cycle), and timing for applications, under each of three specified irrigation treatments--percentage depletion of available soil moisture (100, 80, and 60 percents, respectively) permitted before applying water (a combined 80-100 percentage also was used for certain crops).

2. Measuring changes in soil moisture depletion levels throughout each irrigation cycle during the season. We constructed soil moisture release curves showing progressively lowering soil moisture availability levels during each cycle. These curves, inverted, became soil moisture depletion curves, measuring the progressive reductions in soil moisture availability.

3. Estimating the relationships between depletion levels for available soil moisture and plant growth (hence yield) rates for each irrigation cycle.

4. Establishing the mean growth rates (and yield) for each crop during each cycle according to soils and irrigation treatments, and expressing each as an index representing its percentage of the potential yield possible under physically optimum moisture conditions.

5. Cumulating the growth rates (and yields) for the several cycles into a seasonal yield index for each crop, according to soils and irrigation treatments, assuming a linear relationship for mean cycle growth rates (and yields).

6. Applying the seasonal yield indices from (5) the potential yields estimated to obtain yields associated with each of the various irrigation treatments for crops involved on each soil series-type.

Researchers and Agricultural Extension Service workers provided necessary agronomic data that we used in developing a simple bookkeeping table to evaluate soil moisture requirements for various crops on specific soil series-types, and under particular climatic conditions, using these concepts (see Table 3). This technique rests on the concept that the soil in the plant's root zone is a storage reservoir for moisture. The amount of moisture contained in a foot of soil depth varies among soil types. As evaporation occurs and the plant transpires, the amount of moisture in the root zone diminishes. Gains in this reservoir come from additions in the form of rainfall or irrigation water. The increases shown in Table 1 are adequate in each irrigation cycle to bring the root zone back to field capacity. A water budget, such as that shown, serves two purposes: (a) determines the dates and number of irrigations

TABLE 3

Irrigation Water Budget; Cotton on Hesperia Fine Sandy Loam at
100 Percent Available Soil Moisture
(All quantities in acre-inches)

Month	Root zone depth in ft.	Inches available water		New root zone in.ft. b/	Evapo-trans-piration rate per day	Carry-over c/	From new root zone d/	Moisture at start of period e/	Addi-tions f/	Total avail-able	With-drawal g/	Mois-ture at end of period	Irrigation dates
		per ft. of soil	root zone a/										
1	2	3	4	5	6	7	8	9	10	11	12	13	14
April* 16-30	.75	1.25	.94	0	.020	0	.94	.94	0	.94	.3	.64	
May 1-15	1.00	1.25	1.25	.25	.060	.64	.31	.95	0	.95	.9	.05	
16-31	1.50	1.25	1.87	.25	.080	.05	.62	.67	1.87	2.54	1.2	1.34	May 25
June 1-15	2.00	1.25	2.50	.50	.167	1.34	.63	1.97	2.50	4.47	2.5	1.97	June 12
16-30	2.50	1.25	3.12	.50	.213	1.97	.62	2.59	3.12	5.71	3.2	2.51	June 28
July 1-15	3.00	1.25	3.75	.50	.307	2.51	.63	3.14	3.75	6.89	4.6	2.29	July 10
16-31	3.33	1.25	4.16	.33	.313	2.29	.41	2.70	4.16	6.86	4.7	2.16	July 23
Aug. 1-15	3.67	1.25	4.59	.33	.267	2.16	.41	2.57	4.59	7.16	4.0	3.16	Aug. 10
16-31	4.00	1.25	5.00	.33	.253	3.16	.41	3.57	5.00	8.57	3.8	4.77	Aug. 30
Sept. 1-15	4.00	1.25	5.00	0	.147	4.77	--	4.77	--	4.77	2.2	2.57	--
							5.00		24.99		27.4		

* Assumes preplanting irrigation to bring soil to field capacity.
a/ Moisture available in root zone when soil is at field capacity (col. 2 x col. 3).
b/ Addition to root zone due to expansion of roots into new soil.
c/ Moisture left in root zone at end of time period (amount in col. 13 for last time period).
d/ Moisture now available to plant (col. 5 x col. 3).
e/ (Col. 7 + col. 8).
f/ Moisture added to soil by irrigations to bring soil back to field capacity (col. 9 + col. 10).
g/ Evapo-transpiration rate per day times number of days in time period.

Data in columns 2, 3, 6, and 12 must be obtained from outside sources such as agronomists and irrigation personnel.

necessary for a particular crop on a specified soil within the constraint of a predetermined terminal moisture depletion percentage, and (b) indicates the quantity of water needed to refill the soil reservoir at each irrigation. Thus it provides the mechanism to accomplish Step 1, above.

It was necessary in this study to prepare a separate bookkeeping table and water budget for each of the seven field crops studied under each relevant set of soil-climate conditions for each of the depletion ratios. These calculations recognize changes in root zone depth, and in residual soil moisture in the original and in the newly added root zone for each irrigation cycle (see Table 3). Our example cited here indicates the seasonal growth and ultimate depth characteristics for cotton (Column 2), and how they affect irrigation practices under a 100 percent depletion treatment. It is necessary only to adjust the procedure in accordance with soil, climate, and crop characteristics to apply this bookkeeping water budget approach to other crops. Evapo-transpiration rates, appear in columns 6 and 12. "Addition" (Column 10), is a net figure representing the amount of water needed to bring the soil in the root zone back to field capacity each irrigation. We obtain the amount of water to be applied by dividing this net figure by the expected irrigation efficiency for water at each application (see Table 3).

Inverted Soil Moisture Release or Depletion Curves Represent Soil Moisture-Availability: They Will Serve as Growth Curves

The water budget data in Table 3 illustrate how available soil moisture decreases from 100 percent of field capacity at the beginning of an irrigation cycle to some minimum level at the end. This minimum will be at the permanent wilting point unless the operator elects to apply water before depletion is 100 percent complete. In the Table 3 example cotton roots occupied 1.5 feet of soil, with a field capacity of 1.87 inches of water when the operator added this latter quantity on May 25 (see Columns 2, 4, and 10, Table 1). This application filled the 1.5 foot root zone soil reservoir to its full field capacity. The cotton crop, at the indicated daily evapo-transpiration rates of .080 for May 16-31, and .167 for June 1-15, used 2.4 inches of water between May 25 and June 12. Of this moisture, 1.87 inches represented the May 25 irrigation, and .53 inches moisture already in the added .5 foot of soil (approximately) penetrated by plant roots during the first part of June. These data indicate that 100 percent of all available soil moisture had been released, for all practical purposes, on June 12. Soil moisture depletion had progressed, therefore, until zero amount was available to the plants, and the PWP had been

reached. This 100 percent depletion level is the one used in the illustration to signal that irrigation is necessary. Step 2 was to estimate rates of depletion and prepare moisture release curves according to soil types. Our approach uses the 100 percent level, plus the 80 and 60 percent levels, respectively, to define the three major irrigation practices for analysis. A fourth practice, used for some crops, is the 80-100 percent level, in which the 80 percent level applies to the early portion, and the 100 percent level to the latter portion of the season.

The fundamental physical problem in this study was to establish and measure as accurately as possible the precise relationship between amounts of soil moisture available and plant growth rates during each cycle according to the variations in soil characteristics and irrigation practices; the growth rates, in turn, determine yields. Under our assumptions, changes in depletion levels for available soil moisture, as illustrated in Table 3, provide the basis for resolving this problem and thus accomplishing Step 3.

A major relationship is involved here. Our assumption, based on the empirical findings of plant physiologists, is that plant growth rates are determined by the tenacity with which moisture holds to soil particles. Thus the moisture release curve for a specific soil, showing the relationship between tension (measured in atmospheres) and the level of moisture depletion, can be used to estimate the relative growth rate of a plant during an irrigation cycle. We show a hypothetical moisture release curve as an example in the lower half of Figure 5. Tension (in atmospheres) increases as available soil moisture is depleted. By inverting the lower curve, we obtain the one appearing in the upper half of Figure 5. This inverted curve reflects changes in plant growth accompanying the increases in tension as soil moisture depletion reaches successively higher levels. It shows that plant growth declines progressively from 100 percent of its maximum potential when soil moisture is at field capacity for a particular soil to a zero rate when moisture tension reaches the level associated with the PWP depletion level. The shape of this curve varies with soil type. Soil moisture tension is lower, and growth rates higher, for sandy than for clays at the higher depletion levels (see Figure 6).1/

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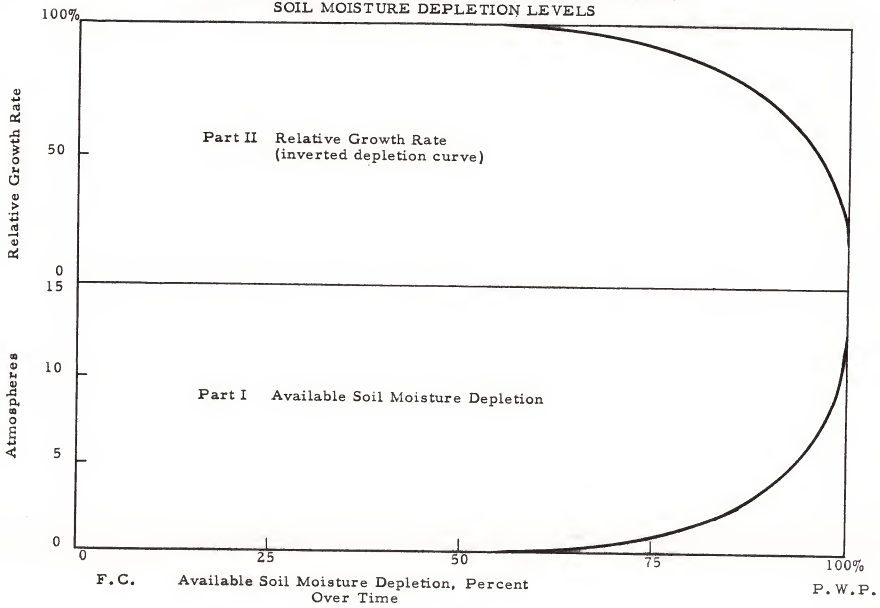
1/ Hagan, op. cit.

FIGURE 5.

SOIL MOISTURE TENSION, RELATIVE GROWTH RATE AND SOIL MOISTURE DEPLETION LEVELS



Plant Growth and Yields Reflect Mean Soil Moisture Availability Levels During the Growing Season

Plant growth rate curves, once estimated, provide the basis for accomplishing the three steps remaining in the procedure outlined above for relating irrigation practices to yields. Step 4 was to determine the mean growth rate for individual irrigation cycles. This rate is at 100 percent of the maximum potential with soil moisture at field capacity following irrigation. It declines, as already shown, from then until another irrigation restores the soil to field capacity. The mean growth rate during an irrigation cycle represents, therefore, the aggregate growth during the time period involved expressed as a percentage of the maximum potential. This is evident graphically if we represent maximum potential growth as a rectangle with the 100 percent growth rate on its Y-axis, and the range from zero to the depletion level marking the end of the cycle on the X-axis (see Figure 7). The area of this over-all rectangle that lies below the growth curve always will be less than its total area, due to the fact that the growth curve does decline. This lesser area (ABRD) when expressed as a percentage of the total for the rectangle bounded on the right by the depletion level at the end of the irrigation cycle (ABCD), represents the mean growth rate for that cycle as a percentage of its 100 percent potential. (See Figure 7.) Our approach in determining seasonal growth rate and yield indices was based on the further assumptions that (a) each irrigation cycle is independent of all others, (b) a linear relation holds between mean growth rates in the individual irrigation periods (see Figure 8). These assumptions enable us to construct a total season growth and yield curve and, hence, the yield index for a particular crop under specified soil and climatic conditions, and according to a predetermined irrigation treatment. Step 5, therefore, was to combine the growth (yield) indices for the individual cycles into seasonal totals. The same method, applied to the various crops under specified conditions, provided a complete set of yield indices for the alternative crops in our study area.

Finally, Step 6 in relating soil moisture availability conditions to crop yields was to estimate physical outputs for the various crops according to seasonal yield indices. We arrived at these estimates by applying the indices to estimated maximum potential yields for each crop under the specified production conditions, as prepared by researchers and other specialists. Thus, if the

FIGURE 6.
VARIATIONS IN RELATIVE GROWTH AND AVAILABLE MOISTURE DEPLETION LEVELS FOR SANDY, LOAM, AND CLAY SOILS

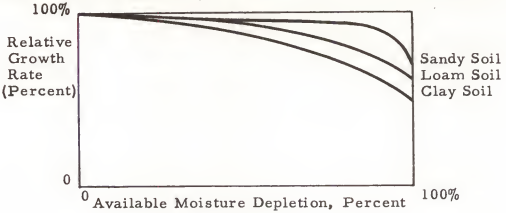


FIGURE 7.
PLANT GROWTH RATES AS PERCENTAGES OF THE POTENTIAL (100 percent) AT INCREASING LEVELS OF DEPLETION FOR AVAILABLE SOIL MOISTURE (Hypothetical Data).

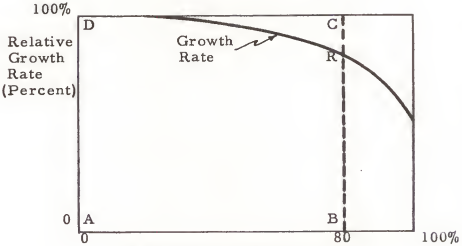
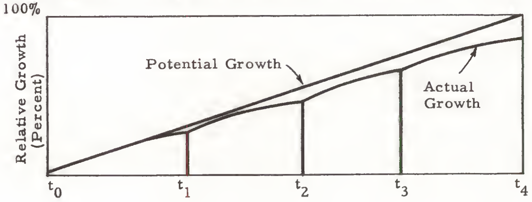


FIGURE 8.
ACTUAL AND POTENTIAL GROWTH BY IRRIGATION CYCLES



normal maximum yield for cotton under given soil, climate, and cultural conditions is three 500-pound bales of lint per acre, the yield under a total season's yield index of 80 percent would be 2.4 bales [3.0 (x) 80 = 2.4].1/

Net Returns per Acre Determine Profit Rankings for Individual Crops

Most farmers on the San Joaquin Valley Eastside have two or more alternative choices in deciding what crop to produce on a particular piece of land. This choice situation presents them with decision problems, particularly when these operators consider variations in physical, economic, and institutional conditions affecting such choices and their financial outcomes. Cotton and sugar beets are the major industrial raw material crops; specialty crops include dry edible beans, cantaloups, potatoes, and alfalfa seed; alfalfa hay, barley, grain sorghum, and corn are the principal feeds. It was necessary in this analysis to prepare detailed summaries of production requirements and costs, outputs and revenue, and net returns-over-variable expenses for each of these crops, usually under two or more sets of conditions. Data for these summaries were obtained by interviews from farmers, commercial agencies serving farmers, and public officials, as well as in published form from available secondary sources. Procedures in preparing summaries involved five steps for each crop under each unique set of conditions:

1. Determining the cultural and harvest operations involved, the timing for each one according to calendar dates, and the equipment, power, labor, and materials involved.

2. Calculating physical quantities for all inputs, including services such as labor, power and machinery hours, plus seed, fertilizer, irrigation water, and other materials.

3. Estimating yields according to the relevant determinants. Thus for each irrigation treatment considered (100, 80-100, 80, and 60 percent available soil moisture depletion, respectively, between irrigations) it was necessary to estimate the appropriate yield, as well as all associated inputs that vary with irrigation practice or yield.

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1/ See Appendix A Procedure for more complete information regarding this estimating procedure.

4. Applying relevant cost rates and prices to express all inputs and yields in dollar values. These calculations included only variable expense items; depreciation, taxes on equipment, and other fixed costs were omitted in this accounting.

5. Summing total variable costs and revenues, according to appropriate classifications, in order to obtain gross receipts, total variable expenses, and net returns-above-variable expenses for each crop.

We excluded fixed costs for this portion of the procedure because its specific purpose is to afford a basis to compare crops and use the resulting data in developing criteria to choose crops and allocate resources. Comparisons within a constant fixed cost structure for the entire farm are entirely feasible for many crucial decisions, and require only minor modifications for others. Thus it simplifies calculations and saves time to omit the fixed costs and concentrate on variable inputs and costs for this analysis.[1/]

Linear Programming Analyzes Alternative Resource Use Opportunities and Identifies Optimum Choices Under Specified Assumptions and Constraints

Restricted quantities and price variations extending into relatively high levels generate irrigation water use problems on California farms. They require farm operators to choose among several competing uses for available water. These operators must make decisions involving complicated interrelationships among these several enterprises, as well as with other necessary resources, within a framework of shifting and uncertain prices. Linear programming offers important advantages as a technique for analyzing such problems. In the words of Heady and Candler, "A linear programming problem has three quantitative components: an objective, alternative methods or processes for attaining the objective, and resource or other restrictions."[2/] A more technical definition states that, " . . . linear programming deals with the minimization of a linear function, subject to the subsidiary conditions that the variables are nonnegative and must satisfy a set of linear equations."[3/]

1/ See Appendix A, Procedure, for more detailed explanations of the method, including samples of the forms used.

2/ Heady, Earl O., and Wilfred Candler, Linear Programming Methods, Iowa State College Press, Ames, Iowa, 1958, p. 2.

3/ Garvin, Walter W., Introduction to Linear Programming, McGraw-Hill Book Company, New York, 1960, p. 3.

We use linear programming technique in this analysis to obtain answers under specified sets of conditions to three types of questions: (a) what enterprises to include in the total farm business (what to produce); (b) how to allocate among enterprises available water and other resources (how much to produce); and (c) in what proportion to combine irrigation water with other materials and services used in producing each product or enterprise (what irrigation practices to use)?

A simple problem including two alternative crops, corn and grain sorghum, and two resource restrictions (constraints), 50 acres of land and 200 acre-feet of irrigation water will illustrate the linear programming method (see Figure 9).

The 50 acres of land, at alternative yields of 20 hundredweights of grain sorghum or 25 hundredweights of corn per acre, can produce 1,000 hundredweights of grain sorghum or 1,250 hundredweights of corn. Available irrigation water will irrigate 67 acres of grain sorghum producing 1,340 hundredweights, or 40 acres of corn producing 1,000 hundredweights. The farmer is limited, therefore, to producing 1,000 hundredweights of grain sorghum (point A) due to the land limitation, or 1,000 hundredweights of corn (point C) due to the water limitation, or to some combination of the two crops that is consistent with both constraints, as defined by the line ABC (see Figure 9). His problem is to decide which crop or crops, and how many acres of each, he should produce to maximize income.

Sales prices are \$2.25 per hundredweight for grain sorghum and \$2.50 per hundredweight for corn. If we draw a constant revenue (isorevenue) line that just touches (is tangent to) the heavy crooked line ABC and has a slope equal to the ratio of the two product prices ($\frac{\$2.50 \text{ corn}}{\$2.25 \text{ g.s.}} = 1.11$), we will find the combination of production that maximizes income. This combination, for our example, includes 525 hundredweights of grain sorghum and 625 hundredweights of corn (point B) with total revenue of \$2,743.75.[1/]

This problem is quite simple with two enterprises (crops) and two restrictions. Thus our problem with seven more enterprises under three (or four)

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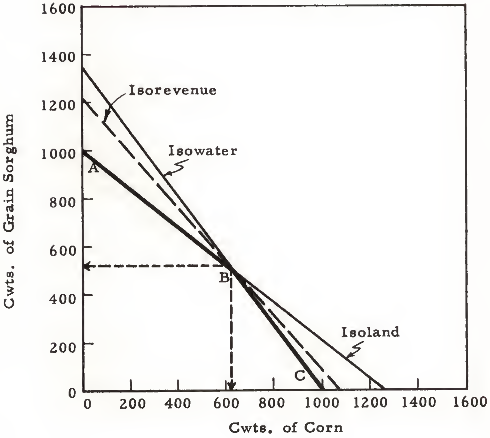
1/ Corn produced to the limit of water available would return \$2,500; grain sorghum expended to the limit of land resources would produce \$2,000 in revenue.

FIGURE 9.
PRODUCTION POSSIBILITY CHART
GRAIN SORGHUM AND CORN



differing irrigation practices, and 18 more restrictions, does not lend itself to solution by this method of simple charts and budget calculations. Restrictions include formal or informal acreage allotments (4), fixed acreages of soils by types (2), and limits on water quantities available in different time periods (14). These, plus the eight enterprises and four irrigation practices, present a problem that is too unwieldy for the graphic method in Figure 9. Linear programming allows simultaneous consideration of all these factors, however, and yields optimum solutions that maximize net farm income under a varying range of conditions. Machine computation made it more manageable, and speeded the analysis.[1/]

Growers seeking to obtain maximum profits from their operations usually try to put as many acres as possible into the crop offering the highest net returns-over-variable expenses. If no constraints exist to interfere, therefore, we would expect an operator on our 640-acre farm model to plant all his irrigable acres in cotton; he would divide these acres between cotton and cantaloups if, for some reason, it is not possible to plant all land to cotton. But constraints do exist; they include physical resource limitations, economic conditions, and institutional forces. We have attempted to recognize such limitations on freedom of management decision through defining a set of 20 constraints that reflect conditions on the farm and in the study area:

Resource Constraints (16)

1. Irrigable land includes 421 acres of Grade I soil and 181 acres of Grade II.(2)
2. Irrigation water is limited to a total of 4,936 acre-feet, and the quantities available during 13 individual irrigation periods vary from about 19 acre-feet per day in the summer months to 27 during May.(14)

Economic and Insitutional Constraints (4)

1. Federal acreage allotments limit cotton acres to not more than 33 percent of irrigable land.
2. Proportionate shares for sugar beets represent a maximum of 12 percent of irrigable land.
3. Necessity for marketing contracts limits cantaloup acres to 15 percent of irrigable land.

1/ See Appendix A Procedure for more detailed explanations of how linear programming is used in this study, including an example of a form.

4. Farmers voluntarily limit blackeyed bean acres to not more than 26 percent of irrigable land, due to market and price uncertainties.

Our analysis includes seven crops; cotton, cantaloups, sugar beets, blackeyed beans, alfalfa hay, grain sorghum (milo), and barley, plus a barley and grain sorghum doublecrop combination. These crops increase to 32 income activities, or processes, in linear programming terminology, since a single crop is listed once for each irrigation treatment, or other input combination and each soil grade. These 20 constraints and 32 income activities establish the framework for the analysis in the following sections. They define the range within which the forces regulating optimum crop choices and resource allocations for maximizing profits under specified conditions must operate.

Important variations exist among farms in the study area, according to whether the operators limit production to a few staple crops, such as cotton, alfalfa hay, and barley, or instead, elect to produce specialty crops in addition. Our analysis recognizes these variations. Thus we examine three different cropping patterns under each set of resource or price conditions (see Figure 10). We identify these alternative cropping patterns by capital letters in the tables and figures accompanying the main body of this report.

A. The analysis includes all alternative field crops listed above.

B. Cantaloups are excluded from the list of alternative crops.

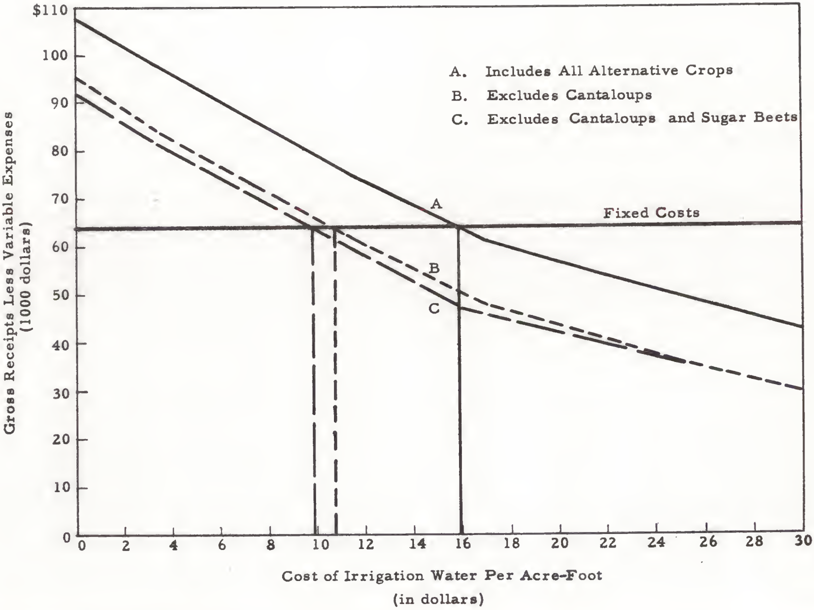
C. The analysis excludes both cantaloups and sugar beets.

Cropping System A represents those farmers in the study area who produce a relatively high percentage of specialty crops; System B reflects the situation on farms where operators allocate only a limited proportion of their total irrigable acres to specialty crops; System C, finally, represents the large percentage of operators who concentrate on staple crops, and exclude specialty crops from their farming plans.

Budgeted Total Farm Earnings Statements Determine Profits and Returns to Various Resource Categories

Linear programming analysis in this study identified the optimum resource pattern and indicated total farm net returns-over-variable expenses under each set of assumptions and conditions examined. This approach, however, did not determine total farm net income, nor measure net profit and the respective

FIGURE 10. FARM NET RETURNS AND IRRIGATION WATER VARIABLE COSTS; THREE CROPPING SYSTEMS.



earnings shares to capital, management, or operator labor. Further analysis is necessary in order to calculate these measures of farm business success under varying water quantity and cost conditions. We used budget analysis for this purpose; this method combines the gross receipts, variable expenses, and net returns yielded by the linear programming with data reflecting capital investments and related fixed costs. It is possible through this combination, therefore, to calculate the necessary earnings measures and (a) evaluate the effect of a given set of conditions on farm resource use, total farm net profits, and the returns to various farm resources, and/or (b) how various plans associated with the respective sets of conditions compare in financial returns and resource earnings.

VARIATIONS IN IRRIGATION WATER COSTS AND IN QUANTITIES AVAILABLE BRING CHANGES IN CROP ORGANIZATION AND NET RETURNS

Sharply Reduced Net Revenues Accompany Increasing Water Costs

The primary objectives in this study are (a) to identify economic choice criteria and, (b) to develop effective measurement techniques for selecting crops and allocating resources, in order to maximize profits. Our first step in analysis was to determine how increasing water costs affect total farm net returns-over-variable expenses. To accomplish this goal, we made a separate linear programming analysis to determine changes in total farm net returns-over-variable expenses for each of the three cropping systems (A,B, and C), as we varied irrigation water variable costs from zero to approximately \$30.00 per acre-foot.1/ Net returns drop sharply on the 640-acre general crop farm as irrigation water expenses increase (see Figure 10). These total farm net returns-over-variable expenses acquire added meaning when we compare them with total farm fixed costs (\$64,000), as shown in Table 2, and as represented on Figure 10 as a horizontal line; where this line intersects the net returns curves defines the "breakeven" point for each of the three cropping systems.

Total farm fixed costs, as calculated in this study, include a return on the operator's actual labor time at hired worker wage rates, but no pay for management as such; earnings on invested capital reflect the estimated values for land and other farm property already indicated above. These breakeven points, may occur, therefore, at net return levels somewhat below what farm operators would find realistic in actual operations. They represent approximations of the points at which managers would obtain sufficient total farm net returns to cover all fixed costs (with no rewards for management services), rather than precise measures.2/

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1/ Irrigation water variable expenses (costs) include only direct cash operating costs for pumped water and tolls paid for surface water. Fixed costs (overhead) such as depreciation, taxes, demand charges, and other items for pumped water, and district assessments for surface water are a part of the total farm fixed costs total, \$64,000 in this study.

2/ Procedures used in this study also assume that the farm operator responsible for enterprise choice and resource allocation decisions has eliminated all technical, price, and other uncertainties, and, therefore, has available all knowledge necessary to make profit-maximizing decisions.

Results from our analyses for these three cropping systems indicate that even farmers who are willing to operate with no return for their own management must expect lower-than-market rates for their capital, and will risk actual capital losses at water variable costs higher than $16.00, $11.00, and $10.00 per acre-foot, respectively under cropping systems (A, B, and C) according to the conditions in this study (see Figure 10). These are the water expenses at which the total farm horizontal fixed cost line intersects the net returns-over-variable expenses lines for the three cropping systems. Losses, as defined above, will occur at all water variable expense levels above the three specified; management returns and profits will accrue at lower prices.1/

Farmers whose production and marketing situations permit them to grow specialty crops, represented by cantaloups and sugar beets in Cropping Systems A and B, can afford to pay more for irrigation water than those not in position to grow these crops. Those in the "C" may be limited by physical conditions, lack of a marketing contract or outlet, or other unfavorable conditions, to strictly staple crops. A wider gap in net returns per acre exists between cotton as the most profitable crop, and the staple crops alternatives in comparison with the margin in earnings between cotton and the specialty crops, under the production and price conditions for this study. The greater the proportion of the land not planted to cotton that operators are able to use in specialty crop production, the higher will be their net returns and the price that they can afford to pay for irrigation water (see Table 4).

Total farm net returns-over-variable expenses for all three systems drop rapidly as irrigation water costs increase. Thus growers with cropping system A, including all alternatives in the study, would receive $108,403 in

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1/ A simple procedure will determine fixed and total costs for irrigation water at the pump head or farm gate, using appropriate estimates for irrigation water variable expenses. Annual fixed or overhead costs for pumping irrigation water under conditions of this study on the 640-acre general crop farms total $13,797 (these costs do not include allowances for farm distribution systems). The rate per acre-foot will vary inversely, according to the quantities pumped; at 3,000 acre-feet, the fixed cost per-acre foot is $4.60; at 2,500 this cost increases to $5.52; at 2,000 acre-feet, it reaches $6.90 per acre-foot and at 1,500, $9.20 per acre-foot. Total water cost per acre-foot equals these fixed costs, plus outlays for irrigation water variable expenses. Thus at $3.00 per acre-foot for this latter item, total costs under the above range of fixed costs will vary from $7.60 to $12.20 per acre-foot. Similar estimates can be prepared for alternative quantities of water and for other levels of irrigation water variable expenses.

TABLE 4

Variations in Farm Net Returns and Irrigation Water Variable Costs; Three Cropping Systems[a]

A-Includes all alternative crops			B-Excludes cantaloups			C-Excludes cantaloups & sugar beets		
Net returns	Expense / acre-ft.	Quantities acre-ft.	Net returns	Expense / acre-ft.	Quantities acre-ft.	Net returns	Expense / acre-ft.	Quantities acre-ft.
1	2	3	4	5	6	7	8	9
dollars		feet	dollars		feet	dollars		feet
108,403	0.00	3,050	95,205	0.00	3,232	92,076	0.00	3,065
98,134	3.36	3,007	86,215	2.76	3,205	84,793	2.40	2,837
96,238	3.96	2,807	84,320	3.36	2,727	83,627	2.76	2,833
75,105	11.52	2,650	61,630	11.64	2,689	81,972	3.36	2,762
74,009	11.88	2,457	50,004	15.96	2,374	47,061	15.96	2,746
63,425	16.20	1,951	49,452	16.20	1,628	46,421	16.20	1,616
61,768	17.04	1,926	48,068	17.04	1,626	26,205	16.32	1,241
59,617	18.24	1,502	46,253	18.24	1,566	29,515	29.88	1,198
53,666	22.08	1,443	35,003	25.44	1,241			
42,558	29.88	1,408	29,515	29.88	1,198			

a/ Gross receipts less variable expenses, fixed costs not considered.

net returns-over-variable expenses at a zero price for irrigation water: this return would fall to the $64,000 fixed cost level at water prices of $16.00 per acre-foot, a reduction of $44,403. This sharp earnings decline represents an average rate of $2,775 reduction in net returns for each $1.00 increase in irrigation water prices (see Table 4). Comparable drops in net returns for the other two cropping systems as water prices rise from zero to the "breakeven" prices are $2,837 and $2,801 per dollar per acre-foot for Systems B and C, respectively.

Farm Net Returns Increase with Water Added at Constant Costs Until Quantities Meet Full Irrigation Requirements

A second important economic question in irrigated farming concerns irrigation water quantities. How do changing amounts of water affect cropping choices, resource allocations, and net returns? A linear programming analysis enabled us to explore this question. We allowed the quantity of water to vary for each of the three farming systems from zero to about 2,800 acre-feet, with variable expenses for water remaining constant at $3.00 per acre-foot. Later this cost is adjusted to zero in the programming solutions in order to determine the added value of production at successive water additions (marginal value products).

Total farm net returns-over-variable expenses rise for each of the three cropping systems as irrigation water quantities increase, at a constant price of $3.00 per acre-foot, from zero to approximately 2,800 acre-feet (see Figure 11). The sharper rates of gain in income are for earlier increases in water inputs. Breakeven points (total farm net returns-over-variable expenses equal to $64,000) occur at slightly over 1,000 acre-feet for Cropping System A, including all alternatives, and at approximately 1,250 acre-feet for the other two systems (see Figure 11 and Table 5).

We would expect this same relationship to hold at other levels for irrigation water variable expense. Breakeven point locations would occur at progressively greater water quantities as water costs increase, until they reach the $16.00, $11.00, and $10.00 prices, and associated quantities, already established by the previous analyses (see Figure 10 and Table 4). Management returns and profits would accrue at each water cost level only at quantities greater than those required to increase net farm returns above the breakeven points.

FIGURE 11. FARM NET RETURNS AT VARYING QUANTITIES OF IRRIGATION WATER; THREE CROPPING SYSTEMS.

(water variable expense $3.00/acre-feet)

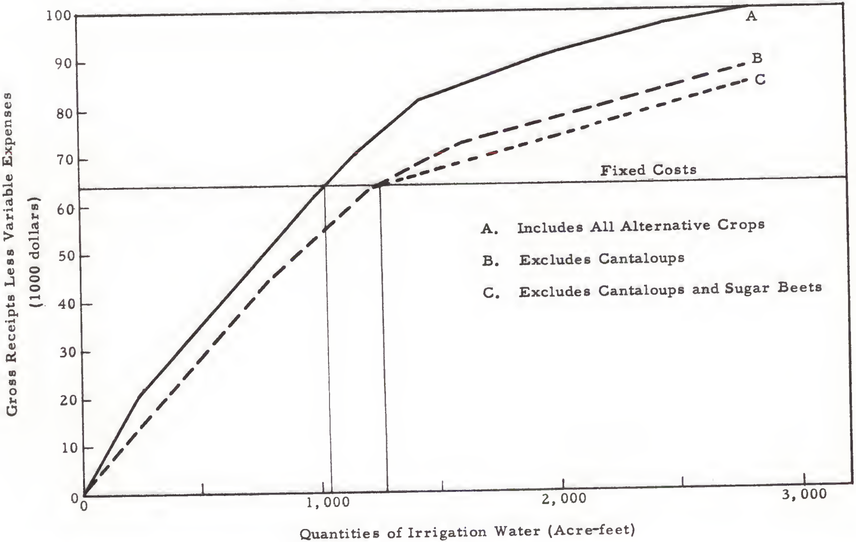


TABLE 5

Farm Net Returns Over Variable Costs at Varying Quantities of Irrigation Water[a/]

Net returns		Irrigation Water		Net returns per acre-foot	
Total	Change	Total	Change		
1	2	3	4	5	6
dollars		acre-feet		dollars	
A. Includes all Alternative Crops					
000	000	000	000	0.00	
19,060	19,060	229	229	83.23	
63,056	43,996	1,009	780	56.41	62.49
68,922	5,866	1,125	116	50.57	
70,681	1,759	1,160	35	50.26	
81,096	10,415	1,408	248	41.99	
82,128	1,032	1,443	35	29.49	
83,546	1,418	1,517	74	19.16	20.90
90,448	6,902	1,926	409	16.87	
90,787	339	1,950	24	14.12	
97,550	6,763	2,457	507	13.34	
99,312	1,762	2,650	193	9.13	
100,641	1,329	2,807	157	8.46	
B. Excludes Cantaloups					
000	000	000	000	0.00	
43,995	43.995	780	780	56.40	
49,861	5,866	895	115	51.01	51.98
62,581	12,720	1,198	303	41.98	
63,842	1,261	1,240	42	30.02	
72,038	8,196	1,563	323	25.37	
73,093	1,055	1,626	63	16.75	15.80
73,130	37	1,628	2	18.50	
83,082	9,952	2,374	746	13.34	
87,134	4,052	2,689	315	12.86	
87,464	330	2,727	38	8.68	
87,489	25	2,735	8	3.12	
C. Excludes Cantaloups and Sugar Beets					
000	000	000	000	0.00	
43,996	43,996	780	780	56.40	
49,862	5,866	895	115	51.01	51.48
62,582	12,720	1,198	303	41.98	
63,843	1,261	1,240	42	30.02	
68,868	5,025	1,616	376	13.36	
83,954	15,086	2,746	1,130	13.35	13.34
84,007	53	2,750	4	13.25	
84,152	145	2,761	11	13.18	
84,153	1	2,762	1	1.00	

a/ Gross receipts less variable expenses, fixed costs not considered.

Sharpest rates of gain in total farm net returns-over-variable expenses per acre-foot of irrigation water available occur for the earlier increments above zero; up to about 1,400 feet for "A", and up to 1,200 acre-feet for Systems B and C (see Figure 11). These rates, and how they change as added water becomes available at a constant price, are extremely important to farm operators. They are particularly concerned with net returns per added acre-foot of available water beyond the quantity required at the breakeven point for total farm net returns and fixed costs, the area in which profits arise. These analyses indicate that under the conditions of this study, operators of farms with the "A" cropping system can expect about $62.00 average adjusted net return per acre-foot of irrigation water for additions prior to the break-even point, and an average of about $21.00 for amounts added from that point up to the 2,800 acre-foot maximum. Comparable data for Cropping Systems B and C are $51.00 and $16.00, and $51.00 and $13.00, respectively. A later section includes more detailed information about how these total farm net returns relate to various crops, as well as to added water available.

Crops Vary Widely in Net Returns to Added Quantities of Irrigation Water

Most farm operators on occasions find it necessary under scarcity conditions to ration the limited quantities of irrigation water available for crop use. Some face this problem practically every season; others only under unusual conditions, such as reduced supplies accompanying years of low precipitation. Regardless of when a farmer must allocate water among competing farm uses, it is highly important that he have effective guides for making sound decisions. He needs reliable information that will enable him to allocate his scarce supplies so as to maximize his earnings.

We undertook to establish such information through a linear programming analysis, in which we determined the changes in total net farm returns, and the dollar value increments (marginal value products) involved in such changes. These data, according to crops responsible for maximum earnings as we varied total annual water quantities from zero to the largest quantity that Cropping System C could use profitably are as follows:

Water		Net returns		Marginal value products (dollars per added acre-foot)		Crops	
Added	Total	Added	Total	@ $3.00	@ $0.00		
acre-feet				dollars		name	acres
895	895	49,862	49,862	55.71	58.71	Cotton	200
345	1,240	13,981	63,843	40.52	43.52	Cotton	200
						B. Beans	160
						Total	320
376	1,616	5,025	68,868	13.36	16.36	Cotton	200
						B. Beans	160
						Alfalfa	61
						Total	421
1,146	2,762	15,285	84,152	13.34	16.34	Same	421
						Alfalfa	181
						Total	602

Clearly cotton offers the highest net return for the first irrigation water and should receive all that can be obtained up to 900 acre-feet. Blackeyed beans, and then alfalfa hay, on Grade I soil as is the cotton, earns the greatest number of dollars per acre-foot for additional water up to about 1,150 acre-feet total for the farm. Finally, if still more water can be obtained, alfalfa hay on the Grade II soil (181 acres) will return $13.34 over the $3.00 price used in this analysis, or a total of $16.34 per acre-foot for an additional 1,146 acre-feet, making a total quantity of 2,762 acre-feet for the System C farm. Marginal value products (dollars added per acre-foot of irrigation water) decline sharply from $59.00 per acre-foot for the first 900 feet used on cotton to $16.00 per acre-foot for the final 1,150 increment applied to alfalfa hay on the Grade II soil.

If an operator under these circumstances has less than the 900 acre-feet of water required for irrigating all 200 acres of cotton properly, he should reduce acreage accordingly. He definitely should not attempt to ration the water among the total 200 acres that would maximize net returns under more favorable water conditions. He would find it more profitable to leave acres idle than to attempt to spread inadequate quantities of irrigation water over too many acres.

The decreasing increments of marginal value products (net returns) accompanying successively added water quantities clearly demonstrate the nature of the problem that farmers with inadequate water supplies face (see Figure 12, upper section). Only through accurate information on such changes in marginal value products to added quantities can such operators be assured that they will obtain highest possible returns to their limited resource, whether it be irrigation water or some other critical item.

Water Costs Exert Major Influence on Farm Organization Decisions

Changing variable expense levels for a major resource, such as water in irrigated farming, quite often causes shifts in the relative profit ranking among farm enterprises. Such shifts, in turn, can bring important changes in crop choices and in resource allocations. Linear programming served in this study to identify the major changes in crop choices and acreages accompanying increases in total irrigation water variable expenses from zero to $32.00 per acre-foot. Results for Cropping System B, indicate that a farmer would need to use five different combinations of crops and acres within the zero to $32.00 range of cost per acre-foot to obtain maximum total farm net returns at each water cost level (see Figure 13).

There is little consistency in the width of the water cost interval that applies to each of the five different farm organizations within the B crop system, under these varying water price conditions. Organization No. 1, with the lowest water costs, offers the most favorable earnings; it is the only one that enables the operator to receive farm net returns equalling or exceeding fixed costs, and represents the optimum cropping pattern for the water price interval from zero to almost $12.00 per acre-foot. Width of the water cost interval for the other four varies from about $4.00 for No. 3 to approximately $7.50 for No. 4 (see Figure 13). One farm organization ceases to be optimum and another assumes this status within the zero to $32.00 range for water costs when the price changes generate enough differences among crops to cause a complete substitution of one crop, or some acreage of one crop, for another or a portion of the acres previously assigned to the first one.

FIGURE 12. CHANGES IN NET FARM RETURNS CROP ACRES AND MARGINAL VALUE PRODUCTS PER ACRE-FOOT OF WATER AT VARYING QUANTITIES OF IRRIGATION WATER.

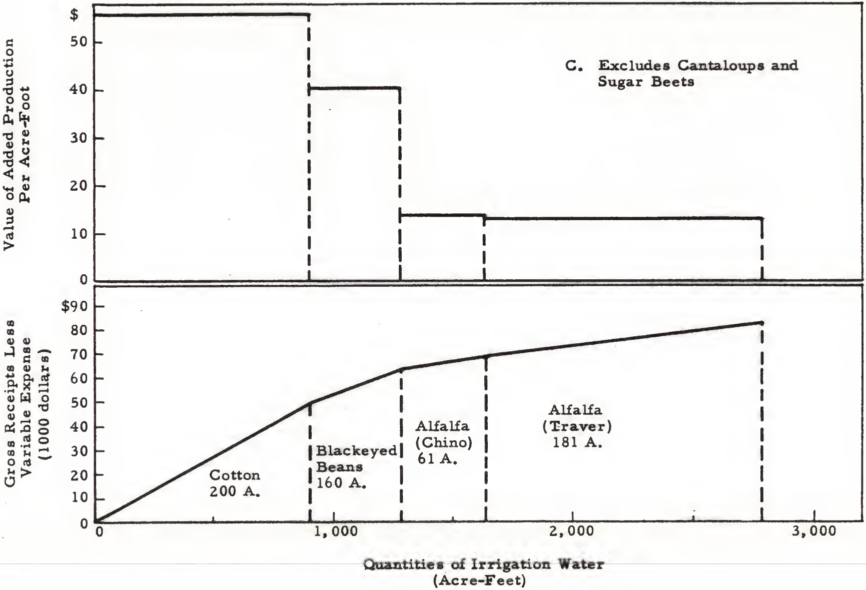
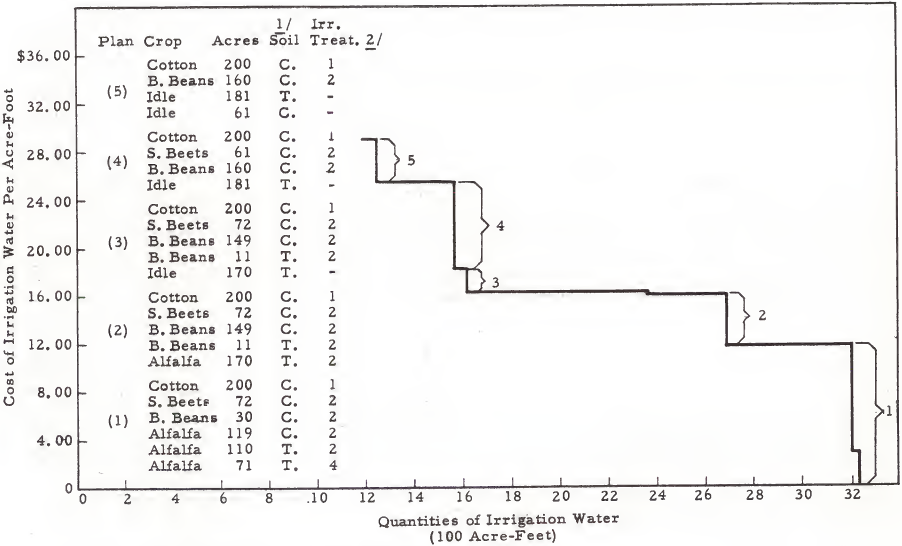


FIGURE 13. OPTIMUM CROPPING PLANS FOR CRITICAL RANGES OF IRRIGATION WATER VARIABLE COSTS.



1/ C = Chino Clay Loam, T. = Traver Fine Sandy Loam

2/ 1 = Irrigation Treatments, 1 = Wet, 2 = Medium, 4 = Dry

Cotton, the most profitable within the group of possible alternatives, dominates all five farm organizations in this analysis; it continues to occupy 200 acres of the top grade Chino land throughout the range of water cost variations. Sugar beets, likewise, maintain their position in the crop organization as water prices rise from zero to slightly more than $18.00 per acre-foot; they drop from 72 acres to 61 in Organization No. 4, and disappear completely in No. 5, the interval with highest water costs (see Figure 13).

Alfalfa hay occupies far more land than blackeyed beans at lower water costs, but disappears in Organization No. 3; the beans gain from 30 acres at the lowest water cost interval to 160 at the most costly rate. Water occupies a much more important relative position in total input requirements and costs for alfalfa hay than for blackeyed beans; this makes the former crop more vulnerable to high water costs, and causes the two crops to shift rank according to net returns as water prices rise.

All Chino (Grade I) soil, continues in production as water costs increase and the cropping patterns change through Plan 4, for which $25.50 represents the upper water cost limit. Organization No. 5, at the upper end of the zero to $32.00 cost range, includes 61 acres of idle Chino soil. All Traver (Grade II) is idle in this plan. A higher cotton acreage allotment, of course, would permit the farm operator to plant more of his land under such high water cost conditions; we explore this question further in a later section. It is quite evident from this analysis that increasing water costs, (a) reduce net returns for enterprises and the total farm, (b) change resource allocations among crops, (c) cause crop acreages to decline and crops to drop out of production as costs become progressively higher, (d) substitute idle land for crop production, beginning with lower quality soils but later affecting the best ones, and (e) finally make economic production impossible. The overall impact of rising water costs is sufficiently serious that operators must make continual analyses and adjustments in order to maintain optimum crop organizations within basic cropping systems. Excessive levels for water costs mean that farmers are unable to utilize part or all of their land and other resources effectively.

Farmers Will Decrease Irrigation Water Use as Water Costs Increase

Analyses reported in the previous sections have indicated that the breakeven points for the three cropping systems under conditions in this

study come at irrigation water variable expenses of approximately $16.00, $11.00, and $10.00 per acre-foot for Systems A, B, and C, respectively. This means that total farm net revenue over variable expenses falls progressively farther short of fixed costs as operators continue to buy water at increasing prices above the breakeven points. Such relationships mean losses on farm investments. We would expect, in these circumstances, that farm operators with accurate knowledge of technical, price, and other relevant relationships would progressively reduce water purchases and use as prices rise; they would increase them as prices drop.

Results from our analysis of quantities of irrigation water associated with optimum organization and net returns for the three cropping systems substantiate this assumption; the familiar economic principle that quantities taken by buyers move inversely to prices for the item being purchased holds for irrigation water on our farm model. Actually earlier analyses reported in sections above clearly indicated such relationships. A specific analysis using linear programming will serve, however, to establish reasonably precise quantitative relationships between water costs and quantities used. These results are quite important whenever questions arise concerning the possible effects of a particular water price, or of some change in an existing price, on the quantities of irrigation water that farmers will purchase. We assume, again, that farmers making the decisions are fully informed, and that they act according to their own best interests; that they choose courses of action leading to optimum organization and net returns. Our analysis shows the changes in water used at a series of water variable cost levels rising from zero to approximately $32.00 per acre-foot. Quite naturally farm operators would use maximum quantities of water at zero prices (see Figure 14). They reduce water use by a series of steps[1/] as costs increase above this level. This same general water use pattern holds for all three cropping systems. Farm operators cut their water requirements in four ways: first, they use drier irrigation treatments on crops already being grown, next they shift land from crops with relatively high to those with smaller water requirements; then, they eliminate crops that become unprofitable

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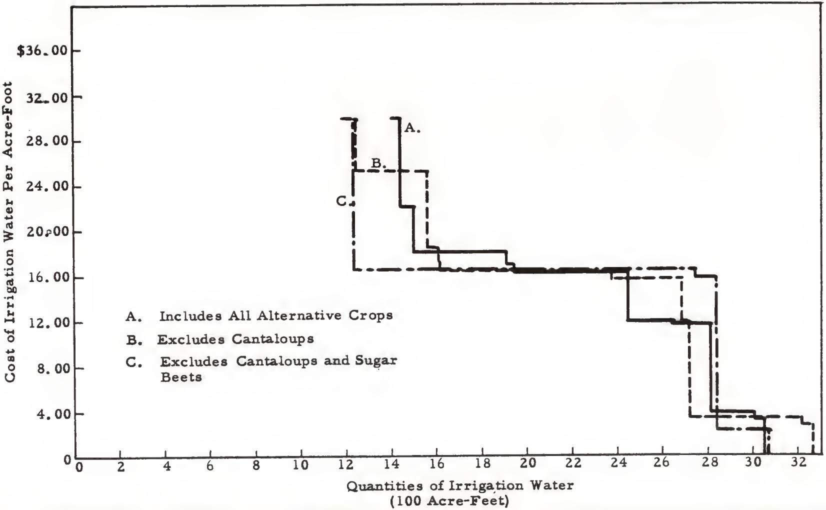
1/ The "stepped" shape of this demand curve reflects two aspects of our procedure in the linear programming analysis; (a) we assume no change in net returns <u>per acre</u> of a crop under a particular set of production and price conditions, regardless of <u>how many</u> acres an operator grows (a linear relationship), and (b) the criteria for computing the "border prices." A particular quantity of water is optimum for the entire price interval of the step (see Heady and Candler, <u>op. cit</u>. Chap. 8).

FIGURE 14. FARM DEMAND FOR IRRIGATION WATER



as water prices rise, thus leaving land idle. The ultimate adjustment, if water costs make profitable farming impossible, is to cease all farm production and go out of business. Farmers take this final step only with great reluctance, and if no other alternative exists. Most operators facing such a choice and course of action usually will accept zero management earnings and reduced return on capital investments for some period of time before going out of business. Capital losses often are unavoidable when farmers undertake to sell farm property for reasons such as these.

How do farmers accomplish the several steps involved in adjusting to rising water costs? Our analyses answer this question according to our assumption that farmers will recognize and follow course of action in their best interests. The changes in crop choices and acreages among the five cropping plans in the previous section provide excellent examples of how farmers shift acreages among crops as water costs increase (see Figure 13). Optimum land use calls for cutting alfalfa hay acreage and increasing that in dry edible beans--a lower water use crop, as water costs rise.

Sharp reductions in water use at approximately the $16.25 per acre-foot level for variable expenses illustrate quite effectively the third step in adjusting to high water costs (see Figure 14). Under the conditions of this study it is not profitable to grow the available alternative crops on Traver (Grade II) soils when water prices reach this level; gross receipts for such production are inadequate to cover variable expenses. Total farm water requirements at the optimum use level, therefore, drop sharply to such quantities as the better soil can use with some net return-over-variable expenses (although this net for the total farm is inadequate to cover fixed costs). The result is a sharp "plateau" effect in the stepped demand curve (see Figure 14).

HIGH WATER COSTS OR REDUCED QUANTITIES CUT FARM PROFITS SHARPLY

Irrigated farming requires large amounts of capital; this capital entails high annual costs. Total average farm investments in farm resources for the 640-acre crop farm model slightly exceed one-half million dollars (see Table 1). Previous analysis has included repeated references to $64,000 in annual fixed costs that accompanies these investment and associated overhead requirements (see Table 2). Interest on farm capital alone, at the assumed market rate of 6 percent, accounts for $30,000, almost half of all fixed costs. Our earlier analyses emphasized the breakeven points--where total farm net returns-over-variable expenses equalled the $64,000 total for fixed costs--as an important criterion for evaluating efficiency in using water and other farm resources. Thus we established that these critical points occur at the $16.00, $11.00, and $10.00 per acre-foot levels, respectively, for water variable expenses under the A, B, and C cropping systems. But these relationships do not precisely define net farm income, farm profits, and management income for our 640-acre model under varying water supply and cost conditions.[1/]

The latter measures not only can be useful in evaluating the results of our analysis for the 640-acre model; they also facilitate comparisons with earnings for other farm sizes and organizations, and with nonfarm businesses. We calculated such measures, therefore, in order to determine how changes in quantity and in costs for irrigation water affect farm profits for the A and C cropping systems. At $3.36 per acre-foot for irrigation water System C (cantaloups and sugar beets excluded) shows $81,972 as total farm net returns-over-variable expenses or a surplus over fixed costs of $17,972 (see Table 6). We obtain net farm income by adding to this amount $1,800 representing costs previously deducted as the value of farm work performed at no cash cost by the operator, and $30,352 for interest on farm capital, likewise previously deducted as a portion of fixed costs, although, it too, is a noncash cost (cash interest payments to others will be required, of course, if the operator owes on his farm capital items). From this net farm income ($50,124) we deducted an imputed value for the operator as a full-time worker, based on hired-worker wage rates. The resulting $46,524 is farm Profit, the return to farm capital and management; it also represents 9.2 percent of the total farm capital (see Table 6). Next we estimated how profit should be divided between

1/ Conventional definitions for the more commonly used farm earnings measures appeared in an earlier footnote (see page 15).

TABLE 6

Farm Profits (Capital and Management Income) Under Varying Water Supplies and Costs; 640-Acre Farm

Item	Limited water supplies	Varying water costs			
		Cropping system C		Cropping system A	
	Quantity 1,616 ac.ft. cost $3.00	$3.36/ac.ft.	$8.00/ac.ft.	$3.36/ac.ft.	$8.00/ac.ft.
	1	2	3	4	5
	dollars				
Total farm capital a/	505,885	505,885	505,885	505,885	505,885
Gross receipts less variable expenses	68,868	81,972	69,000	98,134	84,500
Total fixed costs	64,000	64,000	64,000	64,000	64,000
Net returns over fixed costs	4,868	17,972	5,000	34,134	20,500
Add					
Value operator's work b/	1,800	1,800	1,800	1,800	1,800
Interest on capital	30,352	30,352	30,352	30,352	30,352
NET FARM INCOME	37,020	50,124	37,152	65,666	52,652
Substract					
Operator's wage c/	3,600	3,600	3,600	3,600	3,600
Profit (return to capital and management	33,420	46,524	33,552	62,066	49,052
Interest on farm capital @ 6 percent	30,352	30,352	30,352	30,352	30,352
Management income d/	3,068	16,172	3,200	31,714	18,700
RATE EARNED	6.6	9.2	6.6	12.3	10.4

a/ Average investments in farm property.

b/ Calculated at $1.20 per hour for time in field work, already included in variable costs.

c/ Full-year wages for operator's time at hired worker rates.

d/ Reward for decision making and other management functions.

return on the capital used in the farm business and reward for management per se. To do this, we substracted from total profit the imputed share of capital calculated at an assumed market rate of 6 percent interest--the same rate used in calculating interest as a fixed cost. The result was a value of $16,172 as Management Income; this would be the operator's reward for making necessary decisions, running the business, and risking over one-half million dollars in the farm business.

Similar calculations for other water costs and quantities indicate the impact that varying water cost and quantity conditions can have on profit and other farm earnings measures. An increase from the $3.36 level to $8.00 for water variable costs for System C reduces management income to $3,200. Operators on System A farms fare better in earnings as water costs rise; the same price change as cited for System C would still leave such operators with $18,700 as management income, in addition to the imputed 6 percent return on their capital. Total rates earned under these water prices for System A are appreciably higher than for farms not including the specialty crops.

A serious reduction in water quantity also reacts sharply on farm profits; reducing water available to 1,616 acre-feet, or by over 1,100 acre-feet, with prices at $3.00 per acre-foot shows about the same result for the System C model as an increase in water costs from $3.36 to $8.00 with no quantity changes (see Table 6).

This analysis, using conventional farm earnings measures, further emphasizes the vulnerability of farmers to shift in water availability and costs. This is partly because the earlier analysis, in terms of breakeven points between total net returns-over-variable expenses and fixed costs, included no returns to management as such. The evaluation according to earnings measures also puts the problem of obtaining adequate returns on farm capital in somewhat clearer perspective. It adds greater emphasis and precision to our earlier findings that shortages of irrigation water, or undue cost increases for this resource, can destroy all opportunities for farm profits.

It also is important at this point to repeat that our values for capital invested in land represent approximations based on the most reliable data available; they do not necessarily reflect market values, and the costs to any operator, precisely. To the extent that these estimates for land values, or any other farm property, fall below the true values, our calculations will indicate correspondingly inflated earnings.

FARM PRODUCT PRICE CHANGES CAN CAUSE SHARP VARIATIONS IN WATER USE AND PROFITS

Cotton, cantaloups, and sugar beets are the crop alternatives with highest net returns and profits under conditions of this study. Thus they are the logical candidates for attention in an analysis directed to determining how changes in product prices affect the quantities of irrigation water that farmers use, prices that they can pay for it, and total farm profits. We already know from the results in an earlier section that net farm returns-over-variable expenses and ability to pay for irrigation water increase as farmers add cantaloups and sugar beets to cotton in their cropping systems (see Figure 10 and Table 4). Such gains represent one illustration of how wider ranges of choice contribute to increasing earnings opportunities. We wish to determine, also, how changes in farm product selling prices affect these same farm characteristics, and the opportunity for managers to use added quantities of water profitably.

All three of the high return crop alternatives are subject to production restraints under conditions in the study area, either formal acreage limitations, or such informal arrangements as marketing contracts. Cotton, however, is the one among them that would offer the greatest latitude for expanding production if effective controls were absent. Thus acreage and production did expand sharply under the Plan A-B alternative available to growers in 1959 and 1960. Market breadth, both in the United States and abroad, and relative freedom of cotton lint from deterioration under prolonged storage gives cotton a decided advantage over the other two relatively high-return crops in possibilities for increasing production under favorable conditions. Cotton also is the high-return crop found on practically all general crop farms in the study area. Thus we chose cotton for our special analysis of the relationships between farm product price changes on the one hand, and water costs, quantities used, and farm profits on the other.

Linear programming in this analysis allowed cotton lint prices to vary from zero to approximately 40 cents per pound. Two major assumptions are involved: (a) that acreage allotments and price supports are not in effect, and (b) prices and relative earnings of the other cropping alternatives do not change. Our purpose was to determine how farmers would respond to changes in cotton lint prices under free market conditions. In addition to to the above two assumptions, this analysis is subject to the basic conditions of linearity; it does not consider any possible changes in competitive or

other relationships among enterprises, yield reductions accompanying cotton acreage expansion, or limitations imposed by shortages of capital or other resources.

In order for growers to produce cotton at all two conditions must exist. First, the prices for lint and seed must be sufficiently high that gross receipts from cotton exceed variable expenses. Second, net earnings from cotton must equal or exceed those from the least profitable alternative crop. Otherwise a decision to grow cotton would lead to reduced farm income.

Minimum cotton lint prices of about 18 cents per pound are necessary to bring cotton into the program under conditions in this study (see Figure 15 and Table 6). At this price, cotton replaces alfalfa hay on the Chino soil. Still further rises in lint prices are required to increase cotton production above its initial level. After cotton enters the program, however, a relatively small increase in lint price stimulates sharply expanded production for all three alternative cropping systems (A, B, and C). This response reflects the fact that the optimum cropping program without cotton includes a large acreage of relatively low return alfalfa. Slight increases in lint prices make cotton a more profitable claimant for the resources previously allocated to alfalfa. At a lint price of about 21 cents per pound cotton also comes into production on the lower quality Traver soil.

As a result of cotton's competitive advantage under conditions in this study, lint price rises of 0.4 cents per pound stimulate cotton production expansion to over 700 bales (300 acres) for Systems B and C, respectively. Similar expansion for System A, with a wider range of choice in relatively high return crops, requires about 2.7 cents per pound gain in lint cotton prices (see Figure 15 and Table 7). Further price rises of 0.4, 2.4, and 2.3 cents per pound of lint for Systems A, B, and C, respectively, bring cotton production for each of these systems to about 800 bales (approximately 350 acres at applicable yields).

The <u>rate</u> of production response to rising cotton prices falls off sharply, however, at prices above 21 or 22 cents per pound of lint for all three systems. After reaching 820 bales (about 400 acres) a decidedly sharp increase in lint price is required to increase cotton profits sufficiently above those from other alternative crops for it to displace them in compeition for available resources. Thus at approximately 30 cents per pound for lint, cotton production is about 860 bales for each of the three cropping systems; a further gain of only about 40 bales accompanies price rises of 6.0 to 8.0 cents per

FIGURE 15. COTTON PRODUCTION AT VARYING LINT PRICES WITHOUT ALLOTMENTS.

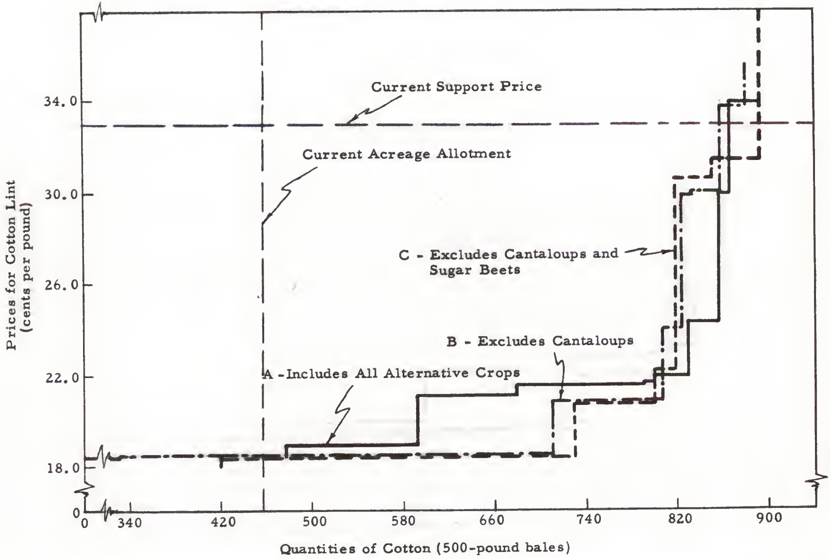


TABLE 7

Cotton Production at Varying Lint Prices Without Allotments

A-Includes alternative crops			B-Excludes cantaloups			C-Excludes cantaloups and sugar beets		
Net returns	Price per pound	Quantities[a/]	Net returns	Price per pound	Quantities[a/]	Net returns	Price per pound	Quantities[a/]
1	2	3	4	5	6	7	8	9
dollars		bales	dollars		bales	dollars		bales
65,989	.000	.0	51,973	.000	.0	48,915	.000	.0
65,989	.184	477.6	51,973	.180	3.6	48,915	.180	419.5
66,916	.188	593.1			170.5	49,402	.183	563.6
73,593	.211	680.2	52,047	.183	331.6	49,876	.184	729.9
75,183	.215	786.8	52,171	.184	712.4	57,572	.205	730.8
			60,616	.208	806.9	58,150	.207	799.6
75,372	.216	799.8				63,650	.221	818.2
76,828	.219	801.4	73,944	.240	822.8	98,354	.306	853.1
77,445	.221	824.6	97,783	.298	829.3	102,151	.314	891.7
86,695	.243	856.3	98,385	.300	855.8	111,090	.334	893.3
109,917	.298	865.8	99,470	.302	863.5	138,995	.397	893.5
127,763	.339	882.4	105,158	.315	867.2			
159,865	.412	898.6	114,551	.337	880.9			
			121,754	.353	885.3			

a/ Bales of 500 pounds gross weight.

pound for the three systems. This reduced response to price gains at higher price levels for cotton shows clearly in the almost vertical lines at the right in Figure 15.

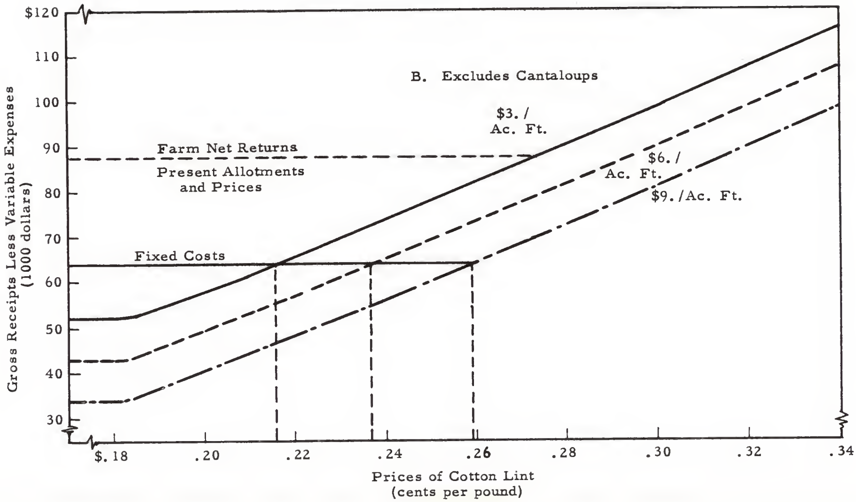
Clearly, cotton production would expand markedly with free market prices higher than 18 cents per pound of lint, provided farmers were free of acreage restrictions. The evidence that cotton would displace other alternative crops at the specified lint prices indicates, therefore, that farmers would be able to cover water variable costs (assumed to be $3.00 per acre foot) as they expand cotton acreage and production in response to rising lint prices. But this information is incomplete because it ignores fixed costs. Farmers must recognize this latter item and recover an equivalent amount in addition to variable expense outlays, if they are to continue in production for any extended period. They might be able and willing to stay in business for one season, or even several, even though net returns-over-variable expenses fail to meet all fixed costs. They certainly could not continue indefinitely under such conditions, even if they were willing; few would be!

An analysis of System B, allowing both cotton lint prices and acreage to vary, indicates how such variations affect net returns and how these net returns relate to total farm fixed costs and, ultimately, to profits. The initial analysis was at $3.00 per acre-foot for irrigation water variable expenses, but we also examined the effects of raising water costs to $6.00 and $9.00 per acre-foot (see Figure 16).

With cotton lint prices less than 18.0 cents per pound (and therefore none produced) gross receipts less variable expenses are about $52,000 for the 640-acre farm as compared with the $64,000 breakeven earnings level at which they equal total farm fixed costs. Farm net returns rise sharply as cotton prices and production increase; they reach the breakeven point with lint prices at about 21.5 cents per pound for System B (no cantaloups). This is evident in Figure 16; the income curve and the line representing the $64,000 fixed cost level on this farm intersect at approximately the 21.5 cents lint price on the X-axis. Returns and profits then continue to rise with cotton prices, but profits do not equal their level under existing acreage restrictions and price supports until lint prices reach 27.5 cents per pound. Cotton production at this price occupies about 400 acres, or double our assumed 200-acre allotment with cotton prices supported at 33.0 cents per pound.

FIGURE 16.

FARM NET RETURNS UNDER VARYING COTTON LINT PRICES WITHOUT ALLOTMENTS.



If water variable costs rise to \$6.00 per acre foot, net returns over all variable expenses do not equal total fixed costs until lint prices reach about 23.7 cents per pound; a further rise in cotton prices to approximately 26.0 cents is required to bring net returns to the breakeven point with water costs at \$9.00 per acre foot (see Figure 16). Operators would allocate about 370 to 380 acres of land to cotton under such price conditions, according to the analysis above (see Figure 15 and Table 7). Profit margins above breakeven net returns would require still higher prices for cotton lint at these higher water costs under conditions of this study. It would require a combination of prices approaching those under existing support levels, plus acreage and production that would accompany such prices in the <u>absence</u> of restrictions, to attain comparable profits.

These results clearly indicate that under free market conditions cotton lint price increases above the 18.0 cents per pound level would stimulate expanded cotton acreage and production. Such gains would be quite sharp and rapid under conditions of this study at prices up to about 22 cents but would continue at a reduced response rate until lint prices reach the 30.0 to 33.0 cent range. If water variable costs remain at the assumed \$3.00 per acre-foot level, total farm net returns-over-variable expenses would equal the \$64,000 fixed costs at about 21.5 cents per pound for Cropping System B. Further gains in cotton lint prices above this level would add to profits. At a lint price of about 27.5 cents they would equal those under the current 33 cent price support, coupled with a 200-acre allotment for cotton; any further rises would bring still higher profits. We conclude, therefore, that for System B gains in cotton lint prices above about 21.5 cents per pound with no acreage allotments would increase the margin of total farm net returns-over-fixed costs. Farmers would be able to use more irrigation water at the \$3.00 per acre-foot variable cost level, or to pay higher prices for the same quantities. How much of this added buying power they would have would depend on the actual magnitude of price rises.

If, in such circumstances, farmers should pay higher prices for water, the result would be to reduce net profits, but not necessarily to lower total farm net returns below the breakeven point. Growers would need to balance any such gains in product selling price carefully against changes in water costs. Thus they would need to receive about 23.7 and 26.0 cents per pound, respectively, for lint with water costs at \$6.00 and \$9.00 per acre foot. Again, further

price increases beyond these indicated at the breakeven points would add to profits and to grower ability to pay for water.

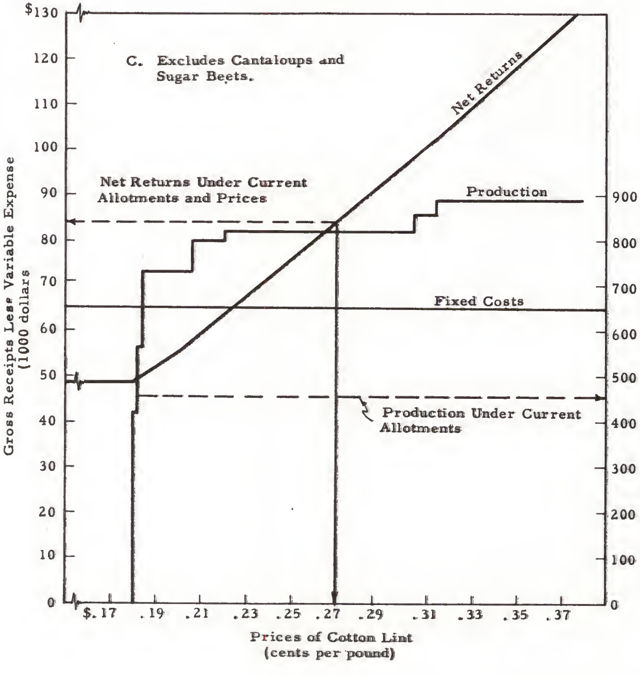
A similar analysis for System A served to identify impacts of varying cotton lint prices with irrigation water variable costs remaining constant at $3.00 per acre-foot for that farming system. Cotton comes into the system at 18.0 cents per pound of lint, after which production increases rapidly with price gains until it reaches over 800 bales at 22.25 cents per pound. It is at this price and quantity for cotton that farm net returns-over-variable expenses equal the $64,000 breakeven level (see Figure 17). Net returns do not attain a level comparable to those under federal supports applying in the early 1960's, however, until lint prices rise to 27.0 cents per pound, and production to well over 800 bales.

A secondary conclusion from this analysis is that cotton acreage and production on the 640-acre general crop farms in the study area would be expanded considerably under free market conditions, as compared with their levels under price supports and acreage restrictions. This appears quite clear from the price-production relationships, even after allowing for errors inherent in the data and the methods. A further confirmation is available in the records of cotton acreage and production expansion in California during the 1959 and 1960 seasons with Plans A and B available to growers.

It is evident, of course, that our conclusions regarding the positive effects of farm product price increases on farmer ability to pay for water are greatly limited in practical application for the study area, as well as in other similar cotton growing areas, as long as price supports and acreage restrictions are maintained at or near current levels. The former greatly exceeds production costs and the level at which sharp acreage increases would occur in the absence of the latter (see Figures 15-17). The general relationships are important for many crops, however, and direct application will be possible for cotton growers whenever the administrative provisions now preventing such applicability are relaxed sufficiently.

FIGURE 17.

COTTON PRODUCTION AND FARM NET RETURNS UNDER VARYING COTTON LINT PRICES WITHOUT ALLOTMENTS.



CONCLUSIONS

Water is the critical resource within the complex of resources and conditions that regulate farm profits on Cotton-General Crop farms in the San Joaquin Valley Eastside. Climatic conditions are such that irrigation water is essential for producing economic yields of practically all crops. Meanwhile, fixed costs and variable expenses for all other resources, at market or going rates, set rigid limits on funds that farmers safely can pay for irrigation water. Operators with their capital already committed dare not exceed these limits on a continuing basis if they expect to obtain satisfactory returns for their own management and supervision, and for hazarding their capital. Indeed, those who do fail to recognize and observe these limits face the likelihood of substandard earnings on their capital, with actual losses a distinct possibility.

A range of $10.00 to $16.00 per acre-foot represents the upper extreme of the cost or price for irrigation water variable expenses that will cover farm fixed costs for a 640-acre Eastside farm under 1956-1960 conditions, allowing no return for management. What will be the actual maximum within this range for a particular farmer operating such a farm will depend in considerable measure upon the proportion of his land that he is able to plant to cotton, specialty crops, and other relatively high-net return enterprises. Obviously, many other conditions and forces will enter into this question if the farm under consideration varies importantly in any respect from the conditions specified in this study. Likewise for water quantities; reductions below 1,000 to 1,200 acre-feet for the 602 irrigable acres in this farm model will, under conditions of this study, prevent the operator from obtaining sufficient net returns-over-variable expenses to cover total farm fixed costs.

We recognize that the above statements, based on the 1956-1960 investments, costs, and prices require additional examination in terms of a longer view toward the future. We would maintain, however, that there is little likelihood of any important reductions in fixed costs or other variable costs for such operations as our 640-acre model in the absence of a major shift toward lower price levels for the entire national economy, except, conceptually, for land. The status of land vis-a-vis the other resources that farmers use in production is such that reduced total farm earnings could react on land values and eliminate important portions of the investments and the fixed costs now included in the

640-acre analytical model. Thus interest on land investments accounts for $23,040 of the $64,000 total for fixed costs. But farmers will not willingly accept such capital losses, often representing the bulk of life-time savings, if any alternative courses of action are available. It appears reasonable, therefore, to expect that only in the most dire emergency will informed farmers plan and continue their operations based on irrigation water variable costs at levels associated with inadequate net returns-over-variable expenses to cover fixed costs, as calculated in this study. Those who have already committed their capital certainly have attempted to assure themselves that water supplies and costs are consistent with profitable farming. Those who have not yet done so may be expected to follow similar policies if and when they do.

Another possible future development is important when evaluating how water quantities and costs react on farm organization, production and profits. This is the question of changes in enterprise earning capacity; such shifts may occur due to price changes for inputs or farm products within the existing marketing, cropping, and production pattern or in yields relative to inputs. They also may reflect improvements in market demand and outlets, permitting expanded acreages of the relatively more profitable crops. Cotton apparently promises little hope along these lines for the foreseeable future. The opportunities for some of the specialty crops, primarily vegetables and fruits, will depend on long-term growth in population, favorable consumer consumption patterns, and overall buying power. Other studies in the University of California have indicated that some acreage and production increases in such specialty crops may be forthcoming during the period extending to 1974 and beyond.

Finally, it is important to note that farmers do have available a number of short-term adjustments to increased water costs, or to reduced quantities available. Most of these, of course, represent stop-gap types of action, such as shifting to drier irrigation treatments, substituting crops with lower water requirements, and leaving less productive land idle. Even so, such expedients may enable a farmer to meet relatively temporary problems concerning irrigation water. Likewise, the distinction between fixed and variable costs may be important in short-term situations. The operator with his capital already committed, and associated fixed costs incurred, may consider it practicable to continue using ground water pumped with his own facilities as long as they last, even though the combined total of fixed plus variable costs for this water may exceed those from an alternative source representing new outlays in their entirety.

APPENDIX

Procedure and Data

APPENDIX TABLE A-1

Growth Rates on Various Soils by Five Percent Intervals for Available Soil Moisture Depletion and Combined Averages; Three Irrigation Practices a/

Percentage intervals for available soil moisture depletion	Growth rates by soil types			
	Clay	Clay loam	Loam	Fine sandy loam
	1	2	3	4
	percentages of potential			
0-15 b/	300.0 b/	300.0 b/	300.0 b/	300.0 b/
15.1-20	100.0	99.0	100.0	100.0
20.1-25	99.0	98.5	100.0	100.0
25.1-30	98.5	98.5	100.0	100.0
30.1-35	98.0	98.0	99.0	100.0
35.1-40	97.5	98.0	98.0	100.0
40.1-45	96.5	98.0	98.0	100.0
45.1-50	96.0	97.5	98.0	99.0
50.1-55	95.5	97.0	98.0	98.0
55.1-60	94.0	96.0	97.0	98.0
60.1-65	92.0	94.0	96.0	97.0
65.1-70	89.0	92.0	95.0	97.0
70.1-75	86.0	88.0	93.0	97.0
75.1-80	82.0	84.0	90.0	96.0
80.1-85	76.0	78.0	83.0	95.0
85.1-90	70.0	68.0	75.0	91.0
90.1-95	62.0	64.0	65.0	81.0
95.1-100	50.0	50.0	50.0	50.0
Sum at 100 percent level	1,782.00	1,798.50	1,835.00	1,899.00
Sum x $\frac{.05}{100}$ (percent)	89.10	89.92	91.75	94.95
Sum at 80 percent level	1,524.00	1,538.00	1,562.00	1,582.00
Sum x $\frac{.05}{80}$ (percent)	95.25	96.12	97.62	98.87
Sum at 60 percent level	1,175.00	1,180.00	1,188.00	1,195.00
Sum x $\frac{.05}{60}$ (percent)	97.91	98.33	99.00	99.58

a/ Irrigation practices include (1) 100 percent, (2) 80 percent, and (4) 60 percent depletion.

b/ The first three five-percent intervals have been consolidated for brevity.

Condensed Basic Computational Form for Linear Programming

Calculations; 640-Acre Farm, Variable Water Prices[a]

Resource or activity at non-zero level	Supply or activity level B	Real activities			P_{21} through P_{58} b/ c/		
		Traver fine sandy loam			Chino clay loam		
		Cotton $2^{d/}$	Cantaloups 1	Barley-G.sorg. $1^{e/}$	Sugar beets 2	Alfalfa 1	B. beans 3
		P_{21}	P_{24}	P_{36}	P_{45}	P_{51}	P_{52}
	C → f/	210.45	199.37	62.73	134.36	92.52	62.54
	1	2	3	4	5	6	7
P_1 Land, Chino c. l.	421 A.	0	0	0	1	1	1
P_2 Land, Traver f.s.l.	181 A.	1	1	1	0	0	0
P_3 Sugar beet contract	72 A.	0	0	0	1	0	0
P_4 Cotton allotment	200 A.	1	0	0	0	0	0
P_5 Cantaloup contract	90 A.	0	1	0	0	0	0
P_6 Water 3/1-15	4,103 A"	7.50	0	5.00	0	0	0
P_7 Water 3/16-31	4,359 A"	0	0	0	15.38	.63	0
P_8 Water 4/1-15	4,157 A"	0	1.52	5.00	6.26	0	0
P_9 Water 4/16-30	4,157 A"	0	3.05	0	0	8.38	0
P_{10} Water 5/1-15	4,937 A"	2.45	9.16	0	8.59	0	0
P_{11} Water 5/16-31	5,193 A"	0	5.42	0	9.71	7.32	7.08
P_{12} Water 6/1-15	3,941 A"	4.90	6.10	7.51	0	9.19	0
P_{13} Water 6/16-30	3,941 A"	10.88	6.65	0	11.76	0	4.04
P_{14} Water 7/1-15	3,620 A"	5.88	0	1.52	0	9.65	6.37
P_{15} Water 7/16-31	3,861 A"	5.93	0	3.05	11.76	7.32	0
P_{16} Water 8/1-15	3,398 A"	6.55	0	9.16	0	7.70	7.08
P_{17} Water 8/16-31	3,625 A"	6.55	0	5.42	0	7.32	0
P_{18} Water 9/1-15	3,393 A"	5.56	0	6.10	0	10.02	0
P_{58} Total water	0	-56.18	-38.68	-61.41	-63.46	-72.54	-24.57
P_{20} Maximum b. beans	160 A"	0	0	0	0	0	1

(Continued on next page.)

Appendix Table A-2 continued.

a/ See also Heady, Earl O., and Wilfred Candler, op. cit., p. 273.

b/ Disposal activities (P_1 through P_{20}) omitted. These serve in calculations to account for resources not used in optimum crop combinations at various prices.

c/ In addition to the examples shown, real activities include: Traver f.s.l., P_{22} Cotton 1, P_{23} Cantaloups 2, P_{25} Alfalfa 3, P_{26} Alfalfa 2, P_{27} Alfalfa 1, P_{28} B. beans 2, P_{29} B.beans 1, P_{30} G. sorghum 3, P_{31} G. sorghum 2, P_{32} G. sorghum 1, P_{33} Field corn 2, P_{34} Field corn 1, P_{35} Barley-Sorghum 2, P_{37} Barley 1; Chino c.l., P_{38} Cotton 4, P_{39} Cotton 2, P_{40} Cotton 1, P_{41} G. sorghum 2, P_{42} G. sorghum 1, P_{43} Cantaloups 2, P_{44} Cantaloups 1, P_{46} Sugar beets 1, P_{47} Field corn 3, P_{48} Field corn 2, P_{49} Field corn 1, P_{50} Alfalfa 2, P_{53} B. beans 2, P_{54} B beans 1, P_{55} Barley-G. sorghum 2, P_{56} Barley-G. sorghum 1, P_{57} Barley 1.

d/ 100, 80, 80-100, and 60 percent levels of available soil moisture depletion prior to irrigation are coded 1, 2, 3, and 4, respectively.

e/ Double cropped. C(net returns) represents sum for both crops.

f/ C line includes net returns over variable expenses per acre for each of the 37 income activities (farm enterprises) plus the 0 for P_{58}, Purchased water.

APPENDIX TABLE A-3

Calculation Methods for Determining Annual Fixed Costs on Farm Property or Capital Goods, (illustrated by 70 drawbar horsepower tracklayer tractor). [a/]

Non-cash costs

1. Interest (6% of average investment)

$$\left[\frac{\text{Original cost + salvage value}}{2}\right] 6/100 = \left[\frac{\$17,160 + \$2,402}{2}\right] 6/100 = \$587$$

2. Depreciation

$$\frac{\text{Original cost - salvage value}}{\text{years on farm}} = \frac{\$17,160 - \$2,402}{10} = \qquad 1,476$$

TOTAL	$2,063

Cash costs

1. Taxes

Assessment @ 35% of average investment = $3,423 x 6,5% levy =	$222

2. Insurance

Estimated @ 0.75% of average investment =	73
TOTAL	$295
ALL FIXED COSTS	$2,358

- -

a/ Fixed costs in this report include "overhead" costs that the farm operator incurs largely regardless of variations in the scope of his annual operations. A heavy proportion of these costs relate directly to land, machinery and other capital goods; some refer to such overhead as "cost of owning" such property, or, simply, as "capital costs." Another important category of fixed costs are those administrative expenses that are unavoidable in the function of managing, but that are difficult if not impossible to allocate to specific income-producing activities, or enterprises. Among this latter group are office expenses, organization dues, social security taxes, and, in this study, irrigation demand charges and district assessments.

APPENDIX TABLE B-1

Estimated Field Irrigation Efficiency Under Furrow Irrigation for Different Application Depths by Soil Type on Deep Well-Drained Soils

Soil type	Desired application depth in inches a/											
	Under < 2	2	2-1/2	3	3-1/2	4	4-1/2	5	5-1/2	6	7	8
	1	2	3	4	5	6	7	8	9	10	11	12
	percentages											
Fine sandy loam	.35	40	45	50	55	60	63	65	65	65	65	65
Loam	.50	55	60	62	64	65	66	67	68	69	70	70
Silt loam	.50	55	60	62	64	65	66	67	68	69	70	70
Clay loam	.50	55	58	60	63	65	65	66	67	66	63	60
Clay	.60	63	65	68	65	62	60	60	58	56	.54	52

a/ Assumes tail water system.

Source: Estimated by research and Agricultural Extension workers in irrigation problems and methods.

APPENDIX TABLE B-2

Irrigation Water Added to Soil, Irrigation Efficiency, and Total Seasonal Applications
by Soils, Irrigation Practices, and Crops, 640-Acre Farm

Crop	Depletion levels for available soil moisture											
	(1) 100 percent			(2) 80 percent			(3) 80-100 percent			(4) 60 percent		
	Water added	Efficiency a/	Total water	Water added	Efficiency a/	Total water	Water added	Efficiency a/	Total water	Water added	Efficiency a/	Total water
	1	2	3	4	5	6	7	8	9	10	11	12
	inches	percent	inches	inches	percent	inches	inches	percent	inches	inches	percent	inches
A. Chino clay loam												
Cotton	30.2	64.6	46.8	34.0	64.5	52.7				33.5	62.3	53.7
Cantaloups	19.4	63.5	30.6	22.0	62.3	35.3						
Sugar beets	38.7	61.8	62.6	40.2	63.3	63.5	42.0	62.6	67.1			
Alfalfa (estab.)	35.3	63.2	55.9									
Alfalfa	51.5	66.0	78.0	52.7	66.0	79.9	52.8	66.0	80.0			
Field corn	23.0	64.8	35.6	27.4	62.3	43.9	23.8	63.7	37.3			
Grain sorghum	20.4	62.6	32.5	22.9	61.6	37.3	25.6	61.9	41.4			
Grain sorghum (late)	20.4	62.3	32.7	22.9	61.6	37.2						
B. Traver fine sandy loam												
Cotton	29.1	56.7	51.3	28.9	51.5	56.2				29.2	43.0	67.9
Cantaloups	18.9	48.9	38.7	22.4	47.1	47.6						
Beans (blackeyed)	14.6	47.8	30.7	14.6	44.8	32.5	14.1	47.1	29.9			
Alfalfa (estab.)	30.7	55.1	55.8									
Alfalfa	50.8	64.2	79.1	52.6	63.6	82.7	52.0	64.2	81.0			
Field corn	24.4	56.7	43.0	27.9	53.1	52.6	24.2	56.0	43.1			
Grain sorghum	19.5	49.5	39.4	23.0	47.6	48.3	20.9	48.0	43.5			
Grain sorghum (late)	19.5	49.5	39.4	23.0	47.6	48.3						

a/ Irrigation efficiencies are seasonal weighted averages of individual water applications.

APPENDIX TABLE C-1

Calendar of Operations and Physical Inputs Per Acre 640-Acre Farm; Cotton on Chino Clay Loam Irrigated Under 100 Percent Soil Moisture Depletion Practice

Dates and operations		Crew and equipment: Men	Power	Equipment	Acres per 9-hr. day	Hours per acre: Man	Tractor	Materials
		1	2	3	4	5	6	7
PREPLANT								
Dec.	Disc (2X)	1	TL-7 (60Hp)	18' offset disc	45	.40	.40	
	Plow	1	W-2 (35Hp)	2-way moldboard 2-16"	9	1.00	1.00	
Jan.	Landplane	1	TL-7	10' x 40' landplane	30	.30	.30	
	Chisel	1	TL-7	3 - 20" shanks	14	.67	.67	
	Disc	1	TL-7	18' offset	45	.20	.20	
	List	1	W-2	4-R	36	.25	.25	
Feb.	Head ditch	1	TL-7	54" ditcher	300	.03	.03	
	Preirrigate	1			9	1.00		
	Fill ditches	1	TL-7	10' scraper	450	.02	.02	
March	Harrow, roll	1	TL-7	30' spiketooth, 30' roller	90	.10	.10	
	Float	1	TL-7	12' x 30'	45	.20	.20	
CULTURAL								
April	Plant	2	W-1 (25Hp)	4-R planter	18	1.00	.50	25 lbs. seed per acre
May	Cultivate	1	W-2	4-R. cultivator	18	.50	.50	
	Cultivate, furrow	1	W-2	4-R	18	.50	.50	
to	Head ditch	1	TL-7	54"	300	.03	.03	
	Irrigate	1			9	1.00		
	Fill ditches	1	TL-7	10' scraper	450	.02	.02	
August	Cultivate, furrow (2X)	1	W-2	4-R	18	1.00	1.00	
	Head ditch	1	TL-7	54"	300	.03	.03	
	Irrigate	1			9	1.00		
	Fill ditches	1	TL-7	10' scraper	450	.02	.02	
	Cultivate, furrow (2X)	1	W-2	4-R	18	1.00	1.00	
	Head ditch	1	TL-7	54"	300	.03	.03	
	Irrigate	1			9	1.00		
	Fill ditches	1	TL-7	10' scraper	450	.02	.02	
	Cultivate, furrow (2X)	1	W-2	4-R	18	1.00	1.00	

(Continued on next page.)

Appendix Table C-1 continued.

Dates and operations	Crew and equipment: Men	Power	Equipment	Acres per 9-hr. day	Hours per acre: Man	Tractor	Materials
	1	2	3	4	5	6	7
Head ditch	1	TL-7	54"	300	.03	.03	
Irrigate (4X)	1			9	4.00		Total water for irrigation = 3.90 acre-feet
Fill ditches	1	TL-7	10' scraper	450	.02	.02	
Chop (2X)			Contracted @ $15.00 per acre a/				
Fertilize (2X)			Contracted @ $3.50 per acre				125 lb. N per acre
Dust (2X)			Contracted @ $7.50 per acre				1 gal. 25% DDT 1-1/2 pint Systox
HARVEST							
Oct.-Nov. Defoliate			Contracted @ $2.50 per acre				15 gal. diesel, 1 qt. dinitro
Pickup (2X)	2	--	2-R S.P.	13	1.40	1.40	
Haul	1	Pickup 1/2T	6-bale trailer	18	.50		
Dec. Cut stalks	1	W-1	2-R cutter	36	.25	.25	
TOTALS					18.52	9.52	
Equipment service time (@ 1/9 operating hours)					1.06	--	
ADJUSTED TOTALS					19.58	9.52	

a/ Contract rates cover only services, excluding all materials costs.

APPENDIX TABLE C-2

Variable Input Expenses Per Acre 640-Acre Farm; Cotton According to Soils and Irrigation Practices[a/]

Input items	Chino clay loam			Traver fine sandy loam		
	percent					
	100	80	60	100	80	60
	1	2	3	4	5	6
	dollars, except as noted					
PREHARVEST						
Power						
Wheel tractor (W-1-25Hp)	1.04	1.04	1.04	1.04	1.04	1.04
Wheel tractor (W-2-35Hp)	4.31	4.31	4.31	4.31	4.31	4.31
Tracklayer tractor (TL-7-60Hp)	3.82	3.82	3.82	3.82	3.82	3.82
TOTALS	9.17	9.17	9.17	9.17	9.17	9.17
Transport						
Pickup truck (1/2 T)	2.48	2.48	2.48	2.48	2.48	2.48
Machinery						
Plow (2 way 2-16")	.50	.50	.50	.50	.50	.50
Chisel (3-20" shanks)	.17	.17	.17	.17	.17	.17
Disc harrow (18' offset)	.21	.21	.21	.21	.21	.21
Landplane (10' x 40')	.12	.12	.12	.12	.12	.12
Spiketooth harrow (30')	.01	.01	.01	.01	.01	.01
Roller (30')	.04	.04	.04	.04	.04	.04
Planter (4-R)	.10	.10	.10	.10	.10	.10
Cultivator (4-R)	.20	.20	.20	.20	.20	.20
Lister (4-R)	.20	.20	.20	.20	.20	.20
Ditcher (54")	.02	.02	.02	.02	.02	.02
Scraper (10')	.01	.01	.01	.01	.01	.01
Stalk cutter (4-R)	.06	.06	.06	.06	.06	.06
Float (12' x 30')	.03	.03	.03	.03	.03	.03
Lister (4-R)	.02	.02	.02	.02	.02	.02
Cultivator (4-R)	.20	.20	.20	.20	.20	.20
TOTALS	1.89	1.89	1.89	1.89	1.89	1.89
Labor						
Specialized	10.82	10.82	10.82	10.82	10.82	10.82
General	14.64	16.42	17.10	15.98	17.45	20.95
TOTALS	25.46	27.24	27.92	26.80	28.27	31.77
Contracted						
Fertilize - materials	15.85	15.85	15.85	14.95	14.95	14.95
- application	3.50	3.50	3.50	3.50	3.50	3.50
Dust and spray - materials	12.50	12.50	12.50	12.50	12.50	12.50
- application	7.50	7.50	7.50	7.50	7.50	7.50
Chop weeds and thin	15.00	15.00	15.00	15.00	15.00	15.00
TOTALS	54.35	54.35	54.35	53.45	53.45	53.45

(Continued on next page)

Appendix Table C-2 continued

Input items	Chino clay loam			Traver fine sandy loam		
	percent					
	100	80	60	100	80	60
	1	2	3	4	5	6
	dollars, except as noted					
PREHARVEST (continued)						
Materials						
Seed	2.75	2.75	2.75	2.75	2.75	2.75
Irrigation water	11.70	13.18	13.43	12.82	14.05	14.31
Labor and materials	5.00	5.00	5.00	5.00	5.00	5.00
PREHARVEST TOTALS	112.80	116.06	116.99	114.36	117.06	120.82
Interest on operating capital	3.54	3.60	3.62	4.00	4.10	4.23
All preharvest costs	116.34	119.66	120.61	118.36	121.16	125.05
HARVEST (yield in 500 lb. bales)	2.09	2.24	2.29	1.90	1.98	1.99
Cottonpicker (2-R)	7.42	7.42	7.42	7.42	7.42	7.42
Pickup truck (1/2 T)	.56	.60	.62	.51	.53	.54
Cotton trailer (6-bale)	.25	.25	.25	.25	.25	.25
Specialized labor	1.87	1.87	1.87	1.87	1.87	1.87
Contracted						
Defoliate - materials	3.00	3.00	3.00	3.00	3.00	3.00
- application	2.50	2.50	2.50	2.50	2.50	2.50
Ginning costs	31.35	33.60	34.35	28.50	29.70	29.85
TOTALS	36.85	39.10	39.85	34.00	35.20	35.35
ALL HARVEST COSTS	46.95	49.24	50.01	44.05	45.27	45.43
ALL VARIABLE COSTS	163.29	168.90	170.62	162.42	166.43	170.48

a/ Irrigation practices identified as (1) 100, (2) 80, and (4) 60 percent levels of available soil moisture depletion, respectively, prior to irrigation.

APPENDIX TABLE C-3

Variable Input Expenses and Net Returns Per Acre 640-Acre Farm; Cotton According to Soils and Irrigation Practices[a/]

Inputs by major group	Chino clay loam			Traver fine sandy loam		
	percent					
	100	80	60	100	80	60
	1	2	3	4	5	6
	dollars, except as noted					
PREHARVEST						
Power	9.17	9.17	9.17	9.17	9.17	9.17
Transport	2.48	2.48	2.48	2.48	2.48	2.48
Machinery	1.89	1.89	1.89	1.89	1.89	1.89
Labor	25.46	27.24	27.92	26.80	28.27	31.77
Contracted	54.35	54.35	54.35	53.45	53.45	53.45
Materials	2.75	2.75	2.75	2.75	2.75	2.75
Water	11.70	13.18	13.43	12.82	14.05	14.31
Miscellaneous	5.00	5.00	5.00	5.00	5.00	5.00
All preharvest costs (including interest)	116.34	119.66	120.61	118.36	121.16	125.05
HARVEST						
Power	7.42	7.42	7.42	7.42	7.42	7.42
Transport	.56	.60	.62	.51	.53	.54
Machinery	.25	.25	.25	.25	.25	.25
Labor	1.87	1.87	1.87	1.87	1.87	1.87
Contracted	36.85	39.10	39.85	34.00	35.20	35.35
All harvest costs	46.95	49.24	50.01	44.05	45.27	45.43
All variable costs	163.29	168.90	170.62	162.42	166.43	170.48
Yields	1,045 lbs.	1,120 lbs.	1,145 lbs.	950 lbs.	990 lbs.	995 lbs.
Price per pound	.33	.33	.33	.33	.33	.33
Lint sales receipts	344.85	369.60	377.85	313.50	326.70	328.35
Seed sales receipts	38.42	41.17	42.08	34.76	36.13	36.59
Total gross receipts	383.27	410.77	419.93	348.26	362.83	364.94
Net returns over variable costs	219.98	241.87	249.31	185.84	196.40	194.46
Net returns plus water costs b/	231.68	255.05	262.74	198.66	210.45	208.77

a/ Irrigation practices identified as (1) 100, (2) 80, and (4) 60 percent levels of available soil moisture depletion, respectively, prior to irrigation.

b/ Net returns under a zero charge for water variable expenses.

APPENDIX TABLE C-4

Variable Input Expenses and Net Returns per Acre, 640-Acre Farm; Summary for All Crops, According to Soil and Irrigation Practices a/

Crops by soil and depletion	a/	Preharvest costs	Harvest costs	Total variable costs	Yields	Price per unit	Gross receipts	Net returns	Net returns plus water costs b/
		1	2	3	4	5	6	7	8
		dollars, except as noted							
Alfalfa hay					(tons)				
Chino clay loam	1	61.53	55.21	116.74	8.09	25.57	206.86	90.12	109.64
	2	62.53	57.87	120.40	8.65	25.57	221.18	100.78	120.74
Traver fine sandy loam	1	65.60	57.35	122.95	8.54	25.57	218.37	95.42	116.10
	2	65.79	59.06	124.85	8.90	25.57	227.57	102.72	122.49
	3	65.73	58.16	123.89	8.71	25.57	222.71	98.82	118.62
Alfalfa Stand									
Chino clay loam	1	56.40	31.23	87.63	4.49	25.57	114.81	27.18	41.16
Traver fine sandy loam	1	58.90	32.53	91.43	4.75	25.57	121.46	30.03	43.97
Alfalfa (comb. 1/4 stand and 3/4 hay)									
Chino clay loam	1	60.25	49.22	109.47	7.19	25.57	183.85	74.38	92.52
	2	61.00	51.21	112.21	7.61	25.57	194.59	82.38	100.84
Traver fine sandy loam	1	63.92	51.15	115.07	7.59	25.57	194.08	79.01	98.01
	2	64.07	52.43	116.50	7.86	25.57	200.98	84.48	102.79
	3	64.03	51.75	115.78	7.72	25.57	197.40	81.62	99.96
					(cwt.)				
Barley									
Chino clay loam	1	38.59	10.71	49.30	31.40	2.16	67.82	18.52	24.02
Traver fine sandy loam	1	38.44	10.26	48.70	28.40	2.16	61.34	12.64	18.14
Beans									
Chino clay loam	1	48.68	40.59	89.27	19.12	8.53	163.09	73.82	79.50
	2	50.47	42.64	93.11	20.40	8.53	174.01	80.90	87.38
	3	49.71	41.42	91.13	19.64	8.53	167.53	76.40	82.54
Traver fine sandy loam	1	53.02	35.85	88.87	16.15	8.53	137.76	48.89	56.55
	2	54.38	36.94	91.32	16.83	8.53	143.56	52.24	60.61
					(lbs.)				
Cotton c/									
Chino clay loam	1	116.34	46.95	163.29	1,045	.33	383.27	219.98	231.68
	2	119.66	49.24	168.90	1,120	.33	410.77	241.87	255.05
	4	120.61	50.01	170.62	1,145	.33	419.93	249.31	262.74

(Continued on next page.)

Appendix Table C-4 continued

Crops by soil and depletion	a/	Preharvest costs	Harvest costs	Total variable costs	Yields	Price per unit	Gross receipts	Net returns	Net returns plus water costs b/
		1	2	3	4	5	6	7	8
		dollars, except as noted							
Cotton (continued)					(lbs.)				
Traver fine sandy loam	1	118.36	44.05	162.42	950	.33	348.26	185.84	198.66
	2	121.16	45.27	166.43	990	.33	362.83	196.40	210.45
	4	125.05	45.43	170.48	995	.33	364.94	194.46	208.77
Fieldcorn					(cwt.)				
Chino clay loam	1	60.81	29.04	89.85	44.80	2.52	112.90	23.05	31.95
	2	65.45	30.40	95.85	48.00	2.52	120.96	25.11	36.09
	3	61.79	29.72	91.51	46.40	2.52	116.93	25.42	34.76
Traver fine sandy loam	1	65.17	30.15	95.32	47.40	2.52	119.45	24.13	34.88
	2	71.09	31.00	101.09	49.40	2.52	124.49	23.40	36.54
Cantaloups					(crates)				
Chino clay loam	1	121.22	351.00	472.22	180	3.80	684.00	211.78	219.42
	2	123.87	374.40	498.27	192	3.80	729.60	231.33	240.16
Traver fine sandy loam	1	126.65	333.45	460.10	171	3.80	649.80	189.70	199.37
	2	131.63	347.10	478.73	178	3.80	676.40	197.67	209.57
Milo-double crop					(cwt.)				
Chino clay loam	1	40.82	12.96	53.78	44.80	2.09	93.63	39.85	48.02
	2	43.34	13.60	56.94	48.00	2.09	100.32	43.38	52.69
Traver fine sandy loam	1	50.85	13.48	64.33	47.40	2.09	99.07	34.74	44.59
	2	55.81	13.88	69.69	49.40	2.09	103.25	33.56	45.64
Milo-single crop					(cwt.)				
Chino clay loam	1	44.86	12.96	57.82	44.80	2.09	93.63	35.81	43.94
	2	46.32	13.60	59.92	48.00	2.09	100.32	40.40	49.64
Traver fine sandy loam	1	54.01	13.48	67.49	47.40	2.09	99.07	31.58	41.43
	2	58.98	13.88	72.86	49.40	2.09	103.25	30.39	42.47
	3	56.30	13.68	69.98	48.40	2.09	101.16	31.18	42.06
Sugar beets					(tons)				
Chino clay loam	1	127.01	56.16	183.17	21.6	13.25	286.20	103.03	118.67
	2	127.52	60.06	187.58	23.1	13.25	306.08	118.50	134.36

a/ Irrigation practices identified as (1) 100, (2) 80, (3) 80-100, and (4) 60 percent levels of available soil moisture depletion, respectively, prior to irrigation.

b/ Net returns under a zero charge for water expenses.

c/ Gross receipts for cotton includes income from both seed and lint sales.

Division of Agricultural Sciences
UNIVERSITY OF CALIFORNIA

ECONOMICS OF ON-FARM IRRIGATION WATER AVAILABILITY AND COSTS, AND RELATED FARM ADJUSTMENTS

3. Some Aggregate Aspects of Farmer Demand for Irrigation Water and Production Response on the San Joaquin Valley Eastside

Charles V. Moore and Trimble R. Hedges

CALIFORNIA AGRICULTURAL EXPERIMENT STATION
GIANNINI FOUNDATION OF AGRICULTURAL ECONOMICS

Giannini Foundation Research Report No. 261 March 1963

FOREWORD

This is the third analytical report to be released as a result of investigations under California Agricultural Experiment Station Project Numbers 1641 and H-1863. Titles of these projects indicate their objectives and subject matter; Economics of Adjustments on California Cotton Farms, and Effects of On-Farm Irrigation Water Supplies and Costs on Cropping Systems and Production Adjustments. The latter-named project is partially supported by funds allocated for that purpose by the University of California Water Resources Center. It also is the California Agricultural Experiment Station supporting project under Western Regional Project Number W-70, Economics of On-Farm Use of Irrigation Water.

Other Experiment Station reports under the general series title for these irrigation investigations include: 1. Enterprise Choices, Resource Allocations, and Earnings on 640-Acre General Crop Farms in the San Joaquin Valley Eastside, 2. Farm Size in Relation to Resource Use, Earnings, and Adjustments on the San Joaquin Valley Eastside, and 4. Subarea Variations in Relations to Resource Use, Earnings, and Adjustments in the San Joaquin Valley Cotton Area. Some Characteristics of Farm Irrigation Water Supplies in the San Joaquin Valley also has appeared as an Experiment Station release, as have various articles in California Agriculture. In addition, several articles in technical journals amplify various aspects of these investigations.

We are indebted to many agencies and individuals without whose generous cooperation neither this report nor others in the series would have been possible. Among these we can list only a few of those upon whom we relied most heavily. The major power companies serving the San Joaquin Valley, Pacific Gas and Electric, and Southern California Edison, authorized us to use well test data previously released to the United States Geological Survey. The latter agency aided greatly in this procedure by making photostatic copies from office records. The California Regional Water Pollution Control Board made well driller reports available to us (data for individual reports are not identified in order to keep both of these sets of information confidential). The California Department of Water Resources also assisted greatly in these studies by making maps, reports, and other information available, as did the United States Bureau of Reclamation. The California Irrigation Districts Association, many individual irrigation districts, and various manufacturers and distributors of irrigation pumps and equipment provided much valuable assistance in the form of factual data and interpretation. We,

of course, drew heavily on published reports and releases of the agencies named here, plus many others.

Among the many individuals to whom we owe appreciation, we wish to mention particularly Messrs. R. S. Ayers, Wm. Balch, D. E. Butler, J. S. Gorlinski, E. J. Griffith, H. H. Holley, G. V. Hufford, J. M. Ingles, F. Munz, B. M. Smith, H. M. Stafford, S. T. Stairs, L. Stennett, and H. D. Wilson. A complete list would extend to a much greater length; we stop at this point only because of space limitations, not for lack of awareness or appreciation of the assistance generously made available by many others.

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SUMMARY

This report presents results of a study concerned with aggregate irrigation water demand and cotton supply response for farmers operating cotton-general crop farms on the San Joaquin Valley Eastside. Its three primary objectives were to develop quantitative measures of aggregate demand for irrigation water, for cotton production (supply) response, and to evaluate the usefulness of these measures to farmers and others responsible for planning resource allocations and production programs in the study area, the central and western portions of Tulare County.

Results obtained in earlier studies of five modal or "typical" farm sizes, representing the bulk of the commercial family-operated cotton-general crop farms in the study area, provide most of the data used here, as well as more detailed information appearing in other reports of this series. These studies indicate clearly that increasing variable costs and varying quantities for irrigation water react sharply, and stimulate definite adjustments in crop choices and resource allocations, on each of the five farm sizes studied. They show an inverse relationship between water costs and both water use and total farm net returns-over-variable expenses, and a positive relationship between quantities of irrigation water available and farm earnings. Farmers adjust to changes in water cost or quantity by varying crop choices, and resource allocations, their specific adjustments depending upon relative net returns per acre, reflecting the interplay of several forces. Important among these latter are water requirements per acre, other input requirements and costs, yields, and product prices for the various alternative crops. Such characteristics for the individual crops reflect physical and biological factors, price-making forces, and government programs and regulations. A wide range of other economic and institutional forces also may be influential; important among these are resource availability and quality and operators' managerial capacity.

In addition to the quantitative data, *per se*, these earlier studies established certain specific relationships that are highly important in conducting and interpreting the results of aggregative analysis. Crop adaptability and performance vary considerably as between the Grade I and the Grade II soils, the first representing 70 and the second 30 percent of all cultivated land. Cotton, the dominant crop, outranks all other alternatives (except certain specialty crops actually grown by only a few operators in the study area) by a relatively wide net returns per-acre margin. This high-return crop, in large part due to

sales prices supported by government programs well above the world market, shows a net return-above-variable expenses per acre at decidedly higher variable costs for water than alfalfa, the next ranking general crop in net returns and total acreage. Acreage allotments, a part of the government price support program for cotton, restrict the acreage for this fiber crop to approximately 30 percent of the total field crop acreage.

Quantitative analysis in this study centers on summing water demand and cotton production response data from the five farm size investigations to obtain aggregate measures for all cotton-general crop farms in the study area. "Stepped" water demand and cotton production schedules for 80-, 160-, 320-, 640-, and 1,280-acre farms, when weighted according to relative numbers in 1954, yield aggregate schedules that also display the "stepped" shape. Steps in these aggregate curves show both more regularity and smaller changes than those for the individual farm sizes. Smooth curves fitted to these two sets of aggregate data, are the basis for calculating elasticity coefficients for each of them. Estimates for total water distributor revenue also were prepared for each price-quantity combination along the aggregate demand curve.

One interesting feature found in the smoothed aggregate water demand curve is the "bench" effect at about the $16.50 per acre-foot price for water. In effect, this break in the curve's continuity means that the aggregate data, as do those for the individual farm sizes, actually describe two discrete water demand curves, one for the prices from zero to $16.50, and the other for the upper range from $16.50 to $30.00 per acre-foot. The explanation lies in the soil qualities, the relative earnings ranks, and the acreage restrictions for cotton, and for certain others among the alternative crops (see above).

Demand for irrigation water appears relatively more elastic at higher price levels than at the lower price ranges, according to this analysis. One percent <u>increase</u> in water price resulted in 0.702 percent <u>decrease</u> in water purchased at the mean for the $16.50 to $30.00 price range, and in 0.188 percent <u>decrease</u> at the mean for the zero to $16.50 range. The elasticity for the entire range of irrigation water prices (zero to $30.00 per acre-foot) is -0.65. These coefficients, inasmuch as they are greater than -1.00 (the coefficient at unit elasticity) indicate that total revenues to water distributors do not decline as water prices rise within the range of prices studied.

The aggregate cotton response analysis indicates that Tulare County cotton production could increase sharply if government price supports and acreage

allotments ended. Such would occur if farmers reacted so as to maximize profits. First, cotton would come into optimum farming programs, defined as those maximizing total farm net returns-over-variable expenses, at 18 cents per pound or slightly more for all farm sizes. Second, the supply elasticity for cotton under conditions of this study indicates 12.0 percent increase in production for each one percent of price rise between 18.0 and 21.5 cents per pound of lint, declining to only 0.30 percent gain in output for each one percent of price increase between 28.5 and 34.0 cents per pound of lint.

Such shifts in acreage allocations from alternative crops to cotton as would be necessary to expand cotton production at the magnitudes suggested above certainly would alter the relative prices for these crops, particularly alfalfa hay, as compared with cotton. Other changes not measured in this study, such as changes in yields for cotton and other crops and inter-enterprise conflicts also probably would arise. Finally projections for California crops by other researchers suggest that substantial acreage and production gains may occur over the period from 1960 to 1975 for fruits, vegetables, and cotton, even if price supports and acreage allotments for the latter crop continue.

All of these uncertainties in the future are important in evaluating the results from this study. It was conducted within a short-term framework, with conditions defined in terms of those prevailing during the period from 1956 through 1960. Any important shifts in these basic conditions, necessarily will require re-evaluation of the findings of these analyses to determine the extent that they apply to the new set of conditions.

ECONOMICS OF ON-FARM IRRIGATION WATER AVAILABILITY AND COSTS AND RELATED FARM ADJUSTMENTS

3. Some Aggregate Aspects of Farmer Demand for Irrigation Water and Production Response in the San Joaquin Valley Eastside

by

Charles V. Moore and Trimble R. Hedges 1/

THIS STUDY COMPLEMENTS AND EXTENDS RESULTS FROM INDIVIDUAL FARM SIZE INVESTIGATIONS 2/

In this report we undertake to identify and determine at least tentative answers to certain critical problems concerning the economics of irrigation water availability and cost, and related water demand and cotton production response for commercial cotton-general crop family farms. The defined study area located in Tulare County on the San Joaquin Valley Eastside also includes an important citrus, deciduous, and vine fruit growing subarea, as well as the cotton-general crop farms investigated in this study (see Figure 1). This circumstance, however, presents no serious problems in this analysis, because geographic locations and soil bodies differ as between the cotton-general crop and fruit farms. Fruit farms, for the most part, occupy the sandy loam soils lying to the north, east and south of the alluvial irrigated portions in Tulare County. Cotton-general crop operations lie to the west of these predominantly

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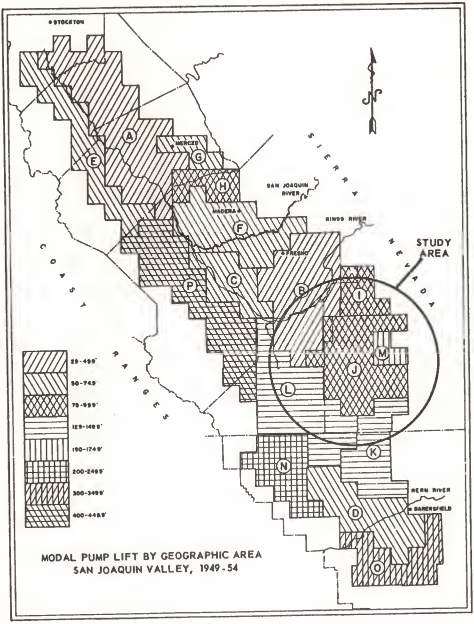
2/ These investigations are authorized under Experiment Station Projects 1641 and H-1863. The latter is a contributing project to W-70. See Hedges, Trimble R., and Charles V. Moore, Economics of On-Farm Irrigation Water Availability and Costs, and Related Farm Adjustments 1. Enterprise Choices, Resource Allocations, and Earnings on 640-acre General Crop Farms in the San Joaquin Valley Eastside, California Agricultural Experiment Station, Giannini Foundation Research Report No. 257, 1962; Moore and Hedges; ______________ 2. Farm Size in Relation to Resource Use, Earnings, and Adjustments on the San Joaquin Valley Eastside. California Agricultural Experiment Station, Giannini Foundation Research Report, 1963; Moore and Hedges, Some Characteristics of Farm Irrigation Water Supplies in the San Joaquin Valley, California Agricultural Experiment Station, Giannini Foundation Research Report No. 258, 1962.

Figure 1


STOCKTON
MERCED
SAN JOAQUIN RIVER
MADERA
KINGS RIVER
FRESNO
STUDY AREA
SIERRA NEVADA
COAST RANGES
KERN RIVER
BAKERSFIELD
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
MODAL PUMP LIFT BY GEOGRAPHIC AREA
SAN JOAQUIN VALLEY, 1949-54

fruit-producing localities; this study, therefore, focuses primarily on this latter, more westerly, portion of Tulare County (see Figure 1).

The present report is one in a series based on an analysis of on-farm irrigation water economics in the San Joaquin Valley cotton-growing area.[1/] This report differs from others in the series in that it deals specifically with over-all area, or aggregate (macro) aspects of irrigation water cost and use, whereas the others considered individual firm (micro) aspects. These analyses and findings, however, as is true for other reports growing out of these investigations, reflect the characteristics, relationships, and economic performance of individual farms in the study area. Our concern here, nevertheless, is with over-all or aggregate problems, those reflecting conditions, relationships, and economic performance for the summation of all such individual farm firms.

Certain questions are central in this analysis: How do variations in irrigation water costs affect quantities used?; What factors govern the rates of changes in price and quantities taken for irrigation water (elasticity of demand) at various price levels? How do variations in the selling price for cotton lint affect cotton production response and total quantities produced?; How do gross receipts for cotton affect farmer ability to pay for irrigation water? What are the opportunities for increased earnings and purchasing power due to crops other than cotton? In addition we explore tentatively in this study the over-all question of the relationship between water pricing and total revenue to distributing agencies.

The results from this study are important to three groups: farmers, other firms and agencies whose operations and financial success are closely identified with those of farmers, and both public agencies and private firms responsible for developing and distributing irrigation water. Still further, the general public has a stake in this over-all question of water development and distribution in view of present resource and production conditions, price and cost relationships, and social, political, and economic forces involved in such development and distribution.

Questions specified above also were important in the earlier reports concerned with individual farm performance. But the results obtained, although important in themselves and basic to the analyses underlying the present report, focused primarily on problems facing operators of individual farm firms of varying

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1/ Loc. cit.

sizes. They stopped somewhat short of the specific information and research results needed to deal with problems of aggregate water use, and to provide a basis for decisions in developing and distributing water, particularly for making additional supplies available. It is for these reasons that the research reported in these pages was conducted.

This Study Has Three Primary Objectives

Analyses reported here had three general objectives: First, to develop quantitative measures of the aggregate demand for irrigation water by operators on cotton-general crop farms in Tulare County; second, to prepare quantitative estimates of cotton production response to varying lint prices (a supply production response curve) on these same farms; third, to evaluate the application and usefulness of the first two kinds of information to decision makers responsible for allocating farm resources and planning production in the study area. Specific questions that must be answered to attain these three over-all objectives underlie the procedures used.

1. What quantities of irrigation water will maximize farm net returns as water variable costs increase (in this analysis, from zero to $30 per acre-foot) for individual farms?

2. What quantities of cotton lint should farmers produce to maximize net farm returns as the price of lint increases (here, from zero to $.40 per pound)?

3. What changes in price-quantity relationships, both for water demand and cotton supply response, occur as farm sizes vary?

4. How do area variations in soils, cropping systems, farm size, and relative per-acre net returns among alternative crops affect both irrigation water demand and cotton supply response?

Assumptions and Procedures in this Study Related Closely to Studies of Individual Farm Sizes

The basic approach in this study consisted, essentially, of four steps: (a) assembling empirical results from earlier studies concerned with irrigation on individual farm sizes ranging from 80 to 1,280 acres, (b) combining these data for five farm sizes weighted according to relative numbers of each size in all Tulare County cotton-general crop commercial farms, in order to obtain aggregate water demand, and cotton supply response curves, (c) examining and interpreting the resulting aggregate curves according to established and accepted economic theory, and (d) evaluating the findings in light of dominant resource, economic, and institutional conditions in the study area, as well

as relative to available projections for future developments in farm product demand and production applicable to the study area.

Results from the earlier studies represented the raw data for most of this analysis; the assumptions underlying this earlier work, therefore, are important to the present analysis. These were as follows:

1. All farmers operating farms of a particular size and with common characteristics will react similarly and in the same degree to changes in production input costs, or to farm product prices.

2. Each farm operator on the "typical" farming units has as his primary objective to maximize net farm returns, subject to the restraints imposed by physical, economic, and institutional forces.

3. All farmers have full knowledge of all technical, price, and institutional phenomena affecting their operations.

The first of these assumptions is the basis for constructing a modal or "typical" farm, rather than undertaking to consider the many variations in age, tenure arrangements, capital availability, and personal preferences existing among individual operators. Only if all such operators are striving for maximum net returns will they necessarily react similarly to a change that indicates specific action required to assure obtaining such earnings levels. The third assumption, concerning complete and accurate knowledge, also is necessary if farmers are to react similarly to the same change in conditions.

Certain other assumptions are inherent in the linear programming method, the basic procedural tool used in this analysis. Of these, the most important is linearity--the characteristic of constant relationship between two or more variables at all combination levels. This assumption implies, that within a particular farm size analyzed by linear programming such characteristics as yields, resource inputs, costs, and enterprise relationships are unvarying for all acreage levels of each activity for each crop.[1/] Secondly, the linear programming model used in this study makes no allowance for the uncertainty and risks involved in production planning, price fluctuations, and technical conditions that the farmer faces. We assume that the farmer has complete knowledge of these factors prior to planting the crops. Finally, the supply and demand

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1/ See Heady, Earl O., and W. Candler, Linear Programming Methods, Iowa State University Press, Ames, for a complete discussion. See also, Hedges and Moore, op. cit., for a discussion of linear programming use and a sample computational table for these studies.

relationships presented in this report are both static and normative in nature. They are static in that they do not include the time factor, or show the path by which farmers adjust from one situation to another. The results are normative, showing what farmers should do and how they should react to maximize income, and not what they have actually done when faced with these situations. The reader is cautioned to keep these assumptions in mind when interpreting the results of this study.

IRRIGATION IS ESSENTIAL; COTTON DOMINATES GENERAL CROP FARMS IN THE STUDY AREA

Results of This Study Apply Primarily to Western Tulare County

Analyses reported here, as in others of the San Joaquin cotton-general crop series, relate specifically to operations in which cotton represents the dominant source of gross receipts and net returns. Since the major objectives of this study center on aggregate measures, it is important to identify the geographic area which these measures are to represent. This area includes all of the alluvial irrigated land in Tulare County of Storie Grades I and II, except for that on which tree or vine fruits represent the principal income source. The latter types of production concentrate in the northeasterly (Cutler and Dinuba), easterly (Exeter, Farmersville, Lindsay, Porterville, Strathmore, and Woodlake), and southerly (Earlimart, Ducor, and Richgrove) localities. They occupy primarily Foster, Greenfield, and Traver fine sandy loam, and Exeter loam soils, although citrus during recent years has moved onto some of the heavier soils in the thermal belt at the eastern extreme of the fruit area.

Farmers Produce Most Irrigated Crops on Grade I or II Soil

A soil survey report with boundaries exactly congruent with those for the study area is not available. A summary based on the Visalia and Hanford survey reports, however, provides a reasonable approximation of soil distribution by quality in the study area. Grade I soils, according to the Storie index, represent 37 percent of all soils in these two survey areas, with Grades II and III accounting for additional 22 and 8 percents, respectively (see Table 1). But farmers apply most irrigation water to crops grown on Grades I and II soils; Grades IV, V, and VI soils representing 34 percent of all soil in the Hanford and Visalia surveys do not lend themselves to producing cotton or other cash crops profitably. Considering only Grades I and II soils, the first accounted for approximately 2/3 of the total for Hanford and Visalia soil survey reports. The proportion reported to enumerators by farmers interviewed in obtaining data

Table 1

Soils by Survey Areas and Grades
Hanford-Visalia Soil Area

Soil classification		Soil survey areas				Total	
		Hanford		Visalia			
grade	index	acres	percent of total	acres	percent of total	acres	percent by grades
1	2	3	4	5	6	7	8
I	90 - 100			108,736	20.0	108,736	43.0
	80 - 89	81,260	58.8	62,848	11.6	144,108	57.0
	Subtotal	81,260	58.8	171,584	31.6	252,844	100.0
	Percent of area total						37.1
II	70 - 79	6,754	4.9	43,776	8.0	50,530	34.0
	60 - 69	33,748	24.4	64,192	11.8	97,940	66.0
	Subtotal	40,502	29.3	107,968	19.8	148,470	100.0
	Percent of area total						21.8
III	50 - 59			33,984	6.2	33,984	66.5
	40 - 49			17,152	3.2	17,152	33.5
	Subtotal			51,136	9.4	51,136	100.0
	Percent of area total						7.5
IV	20 - 39	5,470	4.0	102,464	18.8	107,934	47.0
V	10 - 19	8,768	6.3	28,608	5.3	37,376	16.3
VI	0 - 10	2,240	1.6	82,240	15.1	84,480	36.7
	Subtotal	16,478	11.9	213,312	39.2	229,790	100.0
	Percent of area total						33.6
	Total	138,240	100.0	544,000	100.0	682,240	100.0

Source: Caton, Douglas D., Trimble R. Hedges, and Neill W. Schaller, Inputs and Costs for Producing Field Crops, California Agr. Exp. Sta. Giannini Foundation of Agr. Econ., Mimeo. Rep., No. 203, 1958. (Data from Soil Survey of the Hanford and Visalia Areas, U. S. Bureaus of Soils and Plant Industry.)

for these studies actually was a little higher--they indicated that approximately 70 percent of their land is in the Grade I category, with the balance Grade II. This proportion is the one assumed for all five farm sizes used in this study.

EARLIER STUDIES PROVIDE THE BASIC DATA FOR THIS ANALYSIS

Previous Work Established the Basic Economic Relationships for Irrigated Farming on Five Farm Sizes That Include Most Farms in the Study Area

Detailed results, as reported in the second major release in this series, constitute the primary data used in this analyses. This previous study involves five farm sizes, collectively accounting for the majority of cotton-general crop farms in the San Joaquin Valley Eastside as represented by the segment of Tulare County used as a study area (see Figure 1).[1/] This study used linear programming analysis to determine how (a) changes in water cost, and (b) changes in quantities of water available affect quantities of water used, crop choices and resource allocations, net returns-over-variable expenses, and farm profits on five farm sizes (80, 160, 320, 640, and 1,280 acres). This study also undertook to estimate the cotton lint production response to varying prices in the absence of federal price support and acreage allotments. The primary results of this earlier study are as follows:

1. Data for these five farm sizes, including dominant characteristics, production and resource patterns, technology and production methods, and input-output ratios, are carefully specified according to modal tendencies for these data on farms in the study area. Thus the analytical models represent all commercial cotton-general crop farm operating units in the Tulare County Eastside during the period 1956-1960 as accurately as possible.
2. Linear programming and budget analysis yielded a series of optimum solutions for each of three groups of alternative crops (cropping systems A, B, and C) for each size group under a specified set of conditions and assumptions, and as, first, water variable cost and, second, water quantities vary within specified ranges.
3. This study, concerned primarily with the economics of on-farm irrigation, evaluated three primary irrigation treatments, identified according to the percentage of depletion for available soil moisture when re-irrigation occurs. A fourth treatment is considered in certain instances.
4. Linear programming solutions obtained in the study represents a series of optimi considering soil, grades, water availability, institutional

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1/ Moore and Hedges, op. cit.; ______________ 2. Farm Size in Relation to Resource Use, Earnings, and Adjustments.

restrictions, and other restraints, all three (in some instances four) irrigation treatments, and the specified range first of prices, and second of quantities for water. This same statement holds for optimum levels of cotton lint production within the same framework of conditions and assumptions, with price supports and acreage allotments assumed away.

5. Cotton provides the highest net returns-over-variable expenses per acre on Grade I soil for all farm sizes except the 80-acre model, for which cantaloups rank first and second, considering the several irrigation treatments used. Cantaloups outrank cotton (or first place) on all farm sizes with Grade II soil. Sugar beets and alfalfa hay rank in a middle position according to descending levels of net returns per acre, with grain crops at the lowest levels. 1/

6. Total annual fixed costs average about $100.00 per acre for farms in each size group. This figure, critical in establishing the break-even level of net returns-over-variable expenses for the entire farm, includes irrigation fixed cost (demand charges and overhead on facilities, plus acreage assessment for surface water). Total fixed costs do not include any allowance for returns to the operator for supervision, management, or risking his capital.

7. Farmers on all farm sizes should obtain maximum total net returns-over-variable expenses at zero outlays for water variable expenses. Quantities used, and the magnitude of total net returns drop progressively as water prices increase; break-even levels for total farm net returns-over-variable expenses (the amounts equal to total farm fixed cost) occur at $11.50 per acre-foot for the 1,280-acre model and at $3.50 per acre-foot for the 80-acre unit, both farm sizes including only cotton, blackeye beans, and feed crops as alternatives (System C). Similar relationships appear for farms with a wider range of alternative crops; thus, System A, including cantaloups as a representative specialty crop plus sugar beets, shows comparable break-even irrigation water costs at $17.00 and $7.50 respectively per acre-foot.

8. With water variable costs constant, total farm net returns-over-variable expenses increase consistently as added quantities of water become available.

9. Many shifts occur in crop choices, relative acreages allocated to individual crops, and in irrigation treatments used as water costs rise or as irrigation water quantities increase at constant product price ratios. Marginal value products are relatively high for the initial additions but diminish steadily with later increments. The well-informed farmer should follow a reasonably consistent sequence of adjustments to maintain optimum earnings under conditions of varying water prices or quantities: first, he should reduce irrigation water requirements by shifting to drier treatment for the crops included in his program; next step is to shift land out of

1/ See Appendix Table 1.

relatively high water-use crops and into those with lower water duty; third, at still higher water prices, he will find it necessary to retire lower quality land from use and leave it idle. Fourth, at still higher prices some of the better land will have to be idled; fifth, as water costs continue to rise the farmer may be forced out of business because not even the most profitable crop on his best land will return net revenue to cover all variable expenses.

10. This earlier study provides definite evidence of the advantages that farm operators obtain by increasing farm size. Thus, farmers on 640- and 1,280-acre farms who are well-informed and capable of making sound decisions can operate at decidedly lower average total production cost per unit, and can obtain markedly higher total farm profits than is possible for operators on the three smaller farm sizes included in the study. Farmers are able to obtain the greater part of these scale advantages, however, in adjusting from the three smaller farm sizes to the 640-, or the 1,280-acre farms.

11. Cotton, as the primary crop in the study area in terms of net returns per acre and stability of selling prices dominates resource use and revenues. It is the strongest claimant for limited quantities of irrigation water and, in the absence of price-support acreage controls, farmers would find it to their advantage greatly to expand from 1956-1960 levels of cotton acreage and production. Available evidence indicates that farmers would increase cotton lint production to about double current levels if price supports and acreage allotments were removed, assuming that cotton prices would be in the range of twenty-five to thirty cents per pound of lint.

12. Specialty crops increase farm earnings and strengthen farmer ability to purchase irrigation water on those operating units where satisfactory production and marketing opportunities exist. Substantial improvement in farmers' capability for irrigation water purchases, and in the total farm earnings likely would accompany any important expansion and broadening in the opportunities for operators in the San Joaquin Valley Eastside to expand production of high-returns specialty crops.

Alternative Crops Vary Widely in Net Returns Per Acre

Physical input requirements and total variable expenses per acre vary widely among alternative crops in the San Joaquin Valley Eastside. This is true for any particular soil type; it becomes markedly more evident in making comparisons among different soils, and according to varying irrigation treatments. Thus cotton requires 47 acre inches of water on Chino clay loam and 51 inches on Traver fine sandy loam, under the driest treatment in which irrigation water is applied when available soil moisture is 100 percent depleted.1/ Again, within the Traver fine sandy loam, and still considering the driest treatment, alfalfa requires 64 inches, and dry edible beans 48, as compared with the 57 acre-inches

1/ See Appendix Table 4.

for cotton. Similar variations exist among crops, soils, and technologies for other necessary inputs. The result is that crops differ markedly in total variable input costs per acre. Farm size also reacts upon these variations; variable expenses per acre tend to be higher on the small-sized farms, and to decrease as scale expands with most of the cost gains occurring in size increase from 80 to approximately 640 acres.1/ On the other side of the account, yield variations accompany differences in soils, irrigation practices, and technology. Net returns-over-variable expenses per acre for the individual crops, reflecting both variable expenses and gross receipts, vary widely among crops, soils, irrigation treatments, and other critical factors suggested here.

Net returns-over-variable expenses per acre for individual crops become highly critical in this decision context. The relative ranking of these crops, and therefore the optimum choices and resource allocations, will shift considerably as variable costs for, or quantities of water available, change. Much of the adjustment process that farmers must apply, therefore, as water costs and quantity vary hinges on changing crop choices and resource allocation.

This analysis includes one group of alternative crops in which a specialty crop, cantaloups, ranks in the same net returns bracket as cotton, although operators on relatively few of the cotton-general crop farms in the study area are in a position to produce this specialty crop. Cotton ranks first among the alternative crops on Grade I soil for this cropping system (A), with two of the top three places according to net returns per acre, for all five groups except the 80-acre unit. Cantaloups included in the analysis to represent the specialty crop group, outrank cotton on the 80-acre unit for the Grade I soil and hold two of the top three places for all farm sizes on the Grade II soil. A markedly wide gap exists between the level of net returns-over-variable expenses for cotton or cantaloups on the one hand, and alfalfa hay or sugar beets occupying the middle position for all farm sizes on both soil grades. Feed grains, however, rank at the lowest end of the scale according to net returns per acre for all farm sizes and both soil grades. This pattern followed by the several crops in the distribution according to net returns-over-variable expenses has important implications for aggregate demand analysis appearing in the following major section.

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1/ Moore and Hedges, op. cit.; ______________________ 2. Farm Size in Relation to Resource Use, Earnings and Adjustments.

AGGREGATE DEMAND FOR IRRIGATION WATER REFLECTS INDIVIDUAL FARMER ADJUSTMENTS TO FORCES AFFECTING RETURNS TO THIS RESOURCE

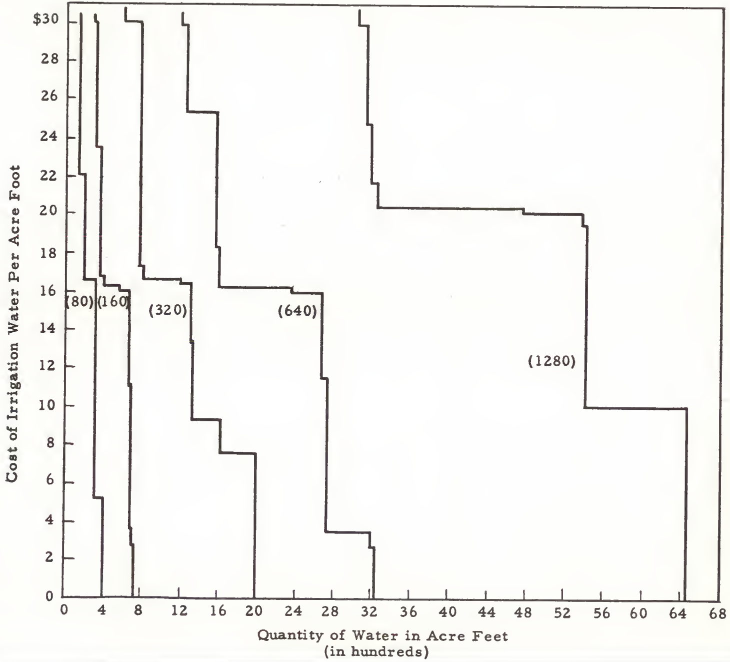
Farmers Adjust Cropping Programs and Resource Allocations According to Variations in Irrigation Water Cost

A farm operator's demand for irrigation water is a derived one; he is willing to pay the cost for water in order to obtain the added profit that he expects it to make possible. The well-informed and capable manager, therefore, will carefully regulate the quantities he is willing to purchase at particular prices to insure that each successive quantity is consistent with his profit maximization goal. He will weigh the added cost of each additional acre-foot of irrigation water against the added dollar returns (marginal value product) that he expects to accrue as a result of adding that last (marginal) unit of water. He should be willing to pay (say) \$3.00 for a last acre-foot of water only if he expects to add farm production equivalent to at least \$3.00 in value as a result. Linear programming techniques determined optimum water quantity and price solutions for each of five farm sizes as the variable cost for irrigation water varies from zero to \$30.00 per acre-foot. The result was a "stepped" demand schedule for the five farm sizes (80, 160, 320, 640, and 1,280 acres) (see Figure 2). These steps, each representing a combination of a quantity of water and a particular price, are not necessarily parallel among the five farm sizes. The amount of water used at a certain price depends upon a specific combination of crops and the acreages of each that return the operator the maximum total net farm returns-over-variable expenses under these particular water cost conditions. Fundamental biological and economical variations among crops, in how soils and climate affect crop performance and yield, and intercrop production cost and price variations, explain these changes in cropping programs that accompany optimum solutions under varying water prices. One particular combination of crops and acreages of each may remain optimum over a relatively wide price range; another combination may be effective for only a very narrow price variation.

Two points are clear from the data yielded by this analysis; first, water prices are extremely influential in determining the quantities that farmers should buy for irrigation purposes; second, the crops grown, and the relative acreages of each under the various solutions within a range of price variations, may vary importantly. These conclusions reflect the basic principle that a farmer's demand for irrigation water is a direct outgrowth of this goal; to maximize his earnings through applying the water to his crops.

Figure 2

Farm Demand For Irrigation Water, Five Farm Sizes



Our analysis reveals a close over-all similarity in stepped demand curves among the five farm sizes. Proportionate changes in water use in response to increased prices are quite similar, even though a cursory examination may suggest otherwise. A more revealing comparison between the 80- and 1,280-acre units is possible, however, after multiplying the horizontal length of each step for the smaller farm by 16 (1,280 divided by 80 equals 16). Following this adjustment, the major discrepancy between the two schedules is that the long step occurring at $16.50 per acre for the 80-acre unit is delayed until about $20.50 per acre for the 1,280-acre farm (see Figure 2). This latter difference reflects the advantage that the large farm has in alfalfa hay harvesting costs.

Relatively short steps for the price range below $16.00 per acre-foot for water variable expenses characterize all farm sizes. These reflect the fact that at the lower price levels farmers should adjust to minor cost increases by using drier irrigation treatments on crops already in their programs, and by shifting from high to low water-use crops in new programs.

AGGREGATE WATER DEMAND AND REVENUE TO DISTRIBUTING AGENCIES RELATE CLOSELY TO ON-FARM IRRIGATION ECONOMICS

Aggregate Demand for Irrigation Water Reflects Physical and Economic Forces

Analytical results presented in the preceding section clearly established the basis for an individual farm operator's demand for irrigation water and some of the important characteristics of this single-firm demand. Additional, and highly useful, information would be an effective measure of aggregate demand for all farms within the area concerned. For the purpose of developing this measure, we used the stepped demand schedule data for the five farm sizes to construct an aggregate area demand schedule. An earlier study had determined the number of farms according to sizes by tabulating all Agricultural Stabilization and Conservation Service cotton allotment records for Tulare County.[1] These totals, classified by farm size groups, provide the basis to construct a weighted area demand schedule. The result was a single set of water quantity-price data in which each of the five farm sizes exerts an importance proportionate to the total quantity of water that farms of this size use in relation to the 2,644 commercial farms in Tulare County with 1954 cotton allotments in the five sizes

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1/ Hedges, op. cit., Economic Adjustments on California Cotton Farms, Preliminary Statistical Summary No. 1. Farms, Acres, and Cost Allotments. 1954.

studied (see Figure 3). This schedule shows greater uniformity and smaller changes among the steps than for the five individual demand schedules, but still exhibits a bench effect or "break" in the middle. By fitting two curves a smooth fit is obtained. These curves describe the relationship between changes in water prices and quantities from zero to $16.50 and from $16.50 to $30.00 per acre-foot, but are discontinuous at the $16.50 cost level (see Figure 3).

Important differences in basic soil productivity as between the Chino clay loam (Grade I) and the Traver fine sandy loam (Grade II) soils included in this analysis, plus the relatively wide differences in net returns levels for the alternative crops available to farmers, largely explain the discontinuous nature of irrigation water demand in this analysis. Government programs and other less official restrictions on freedom of choice also are important. Cotton ranks along with the high gross value specialty crops in net returns-over-variable expenses per acre. Alfalfa hay, a heavy water use crop, ranks distinctly lower than cotton. The combined result of these soil and crop characteristics is that when water variable cost levels reach about $16.50 per acre-foot, alfalfa hay no longer will produce enough gross receipts to cover all variable expenses. Farm operators, therefore, incur losses if they continue to produce alfalfa on the Traver soil, but they have no better generally available alternative.1/ As a result, all Traver soil should go out of production at the $16.50 per acre-foot level, sharply reducing the quantity of water required. In contrast all land, both Chino and Traver should be cultivated at prices below $16.50 per acre-foot. Thus the discontinuous nature of the price-quantity relationship: At water variable expense levels below $16.50 per acre-foot, it permits 100 percent of all farm land to be cultivated; At prices higher than $16.50 per acre-foot, it permits only 70 percent, the Chino soil, to be cultivated.

A regression equation, fitted to each segment of the stepped demand curve by the method of least squares yielded demand schedules. These data, based on the mid-points of the vertical segments of the steps as observations, appear here as two smooth curves (see Figure 3). The assumption in using the mid-points for

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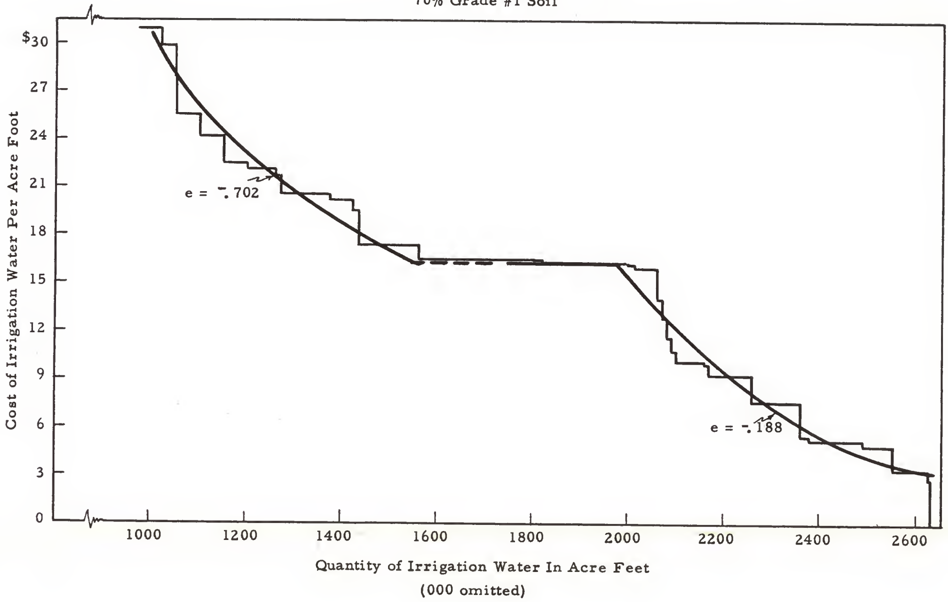
1/ Excluding specialty crops and sugar beets, also subject to acreage restrictions, alfalfa hay, even though less profitable than cotton, yields decidedly higher returns than other alternative crops. See Appendix Table 1.

Figure 2

Demand For Irrigation Water
Cash Crop Farms, Tulare County
70% Grade #1 Soil



this purpose is that they are the most stable points on the stepped curves with respect to price change.[1/]

Demand Elasticities Are Greater at Higher Prices

The next approach in examining aggregate demand for irrigation water under conditions of this study was to calculate demand elasticities for the two segments of the smoothed aggregate demand schedule, and for the entire price range. Demand elasticity change in quantity of a good taken in response to a one-unit change in its price) is a useful abstract measure for characterizing the relationship between prices and quantities taken. Our assumption in calculating demand elasticity coefficients is that price operates as a causal factor (an independent variable), with changes in the quantity of water taken (the dependent variable) occurring in consequence of the price changes. An elasticity of 1.00 for water indicates that one percent <u>increase</u> in the price brings with it a one percent <u>decrease</u> in the quantity taken, if other related conditions remain constant. In this analysis, considering the entire range of water prices (variable costs) evaluated, one percent increase in price caused 0.65 percent decrease in the quantity of water purchased. For the mean of the water-cost range from $16.50 to $30.00 per acre-foot, one percent rise in water prices resulted in 0.702 percent decrease in quantity taken. At the mean of the lower end of this range (water variable costs zero to $16.50 per acre-foot) one percent increase in price causes 0.188 percent decrease in the quantity of water taken (see Figure 3). Thus the elasticity coefficients serve as a concise summary of the tendency for steadily rising water prices to cause quantities taken to decrease at progressively more rapid rates. Stepped demand curves for all five farm sizes, as well as the combined aggregate demand curve, clearly indicate this tendency.

Total Revenue to Water Distributing Agencies Declines with Lower Water Prices Under Inelastic Demand Conditions

If demand is inelastic (the coefficient of elasticity is less than 1.00, a drop in water prices will reduce gross receipts (total revenue)). This effect is evident in this study from the total revenue curves constructed from the demand curves fitted by regression methods (see Figures 3 and 4). We calculated

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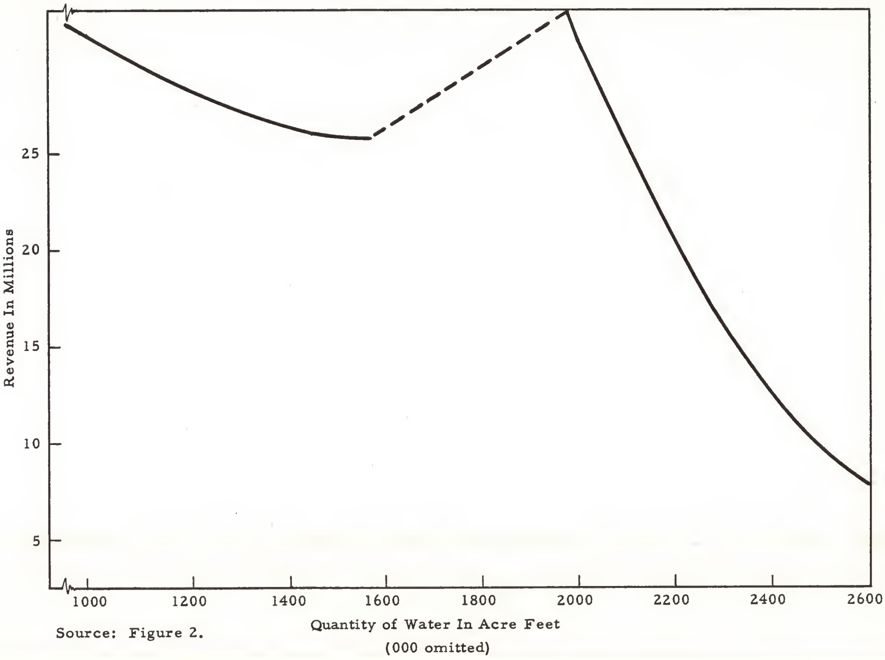
1/ Equations were as follows: Upper segment: $y = 113.7186 - 12.125X + .381X^2$

Lower segment: $y = 178.903 - 12.878X + .2351X^2$

Data such as those used in these calculations do not meet the necessary assumptions of normality and independence used in regression analysis and, therefore, do not support statistical inferences and probability statements.

Figure 4

Total Revenue From Sales of Irrigation Water To Cash Crop Farms, Tulare County



Source: Figure 2.

total water sales revenue by multiplying each price along the smooth demand curve by the associated quantity. Inasmuch as the two segments of the discrete demand curves have different slopes, so also do the revenue curves derived from these two segments. The segments of the demand curve including the lower price range is much less elastic (is more inelastic) than the segment at higher prices. This variation has different and important revenue implications for the two portions of this curve. The more inelastic a demand curve, the greater will be the increase in revenue that accompanies a rise in price for the commodity. Conversely, the sharper will be the revenue drop if prices fall. These relationships explain the differential revenue levels at the different points along the two revenue curve segments. The segment at the left shows gross receipts from selling water at prices higher than $16.50 per acre-foot. The dotted line represents the discontinuous break in the original stepped curve and in the smooth demand curves. Finally, the curve segment at the right represents water revenues obtained at sales prices less than $16.50 per acre-foot (see Figure 4). Identical total revenues can be obtained at differing water prices; for example, 46.4 million dollars results either from selling 1.5 million acre-feet at $17.60 per acre-foot, or 2.08 million acre-feet at $12.70 per acre-foot.

Pricing policies vary with distributors.--Elasticity-revenue relationships indicated above have important policy implications. A distributor, such as an irrigation district, with the policy of charging just enough for irrigation water to cover total costs would choose a price at a distinctly different point on the demand curve than a private, profit-seeking company whose goal is to maximize profit.1/ It is not possible to identify the precise points on the revenue curves for attaining each of these two objectives without considerably more information than is available here. An absolutely essential item is detailed knowledge regarding the total costs for storing and distributing various quantities of water--cost curves; other facts and data also are required. We can specify the governing principles: An irrigation district, to meet the above goal, would price water so that total revenue would just equal total cost. The private water company, seeking profits, would price water to maximize the difference between total cost and total revenue.

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1/ See Brewer, M. F., Water Pricing and Allocation with Particular Reference to California Irrigation Districts, California Agr. Exp. Sta. Giannini Foundation Mimeographed Report No. 235, Oct. 1960, for additional discussion of this subject.

In practice, irrigation districts using a combination of levies based on real estate assessments and measured toll rates should follow a definite procedure: first, determine total costs to be met; second, subtract the revenue obtained from real estate levies from the total cost; and third, establish toll rates to obtain the difference when levied against the expected volume of water delivery. Maximum quantities of water will be used, and the highest physical production by farmers will be forthcoming, under a policy of obtaining a relatively high proportion of total distributor income through levies on real estate assessments. Absolute maximum quantities will be used when all income is derived from such levies. At the other extreme, the smallest total quantity of water will be sold if all income is obtained from metered toll charges. The discrepancy between the two quantities involved widens as demand elasticity increases up to -1.00.

Adjusting the Water Demand Curve for Soil Quality Variations

Soil quality variations present serious problems in undertaking to construct an aggregate demand curve for a particular geographic area. Our analysis has assumed that all farms studied, regardless of size, include 70 percent Grade I and 30 percent Grade II soils. Such uniformity in soil resources among a group of farms within an area is not characteristic. On the contrary, most large geographic areas are characterized by varying soil grades. Some farms will contain 100 percent Grade I, and no Grade II soils. Others will vary through the entire possible range of proportions to the opposite extreme, 100 percent Grade II soil. Data indicating the proportion of soils by grades according to size of farms are not available for this study. The next best alternative in the absence of such data is to specify several different proportions and then to aggregate, still assuming that all farms contain the same proportions. The result of this procedure is a three-dimensional surface with traces for five different proportions of total soil resources in Grades I and II soils (see Figure 5).1/ Such a surface permits some evaluation of how variations in soil quantity among different farms may affect demand for irrigation water. The 75 percent trace on this figure represents a close approximation of the stepped demand curve, smoothed by regression methods, previously presented (see Figures 3 and 5). The long horizontal step at the $16.50 per acre-foot water available cost level is apparent for all soil quality traces. Due to alfalfa going out of production with no alternative

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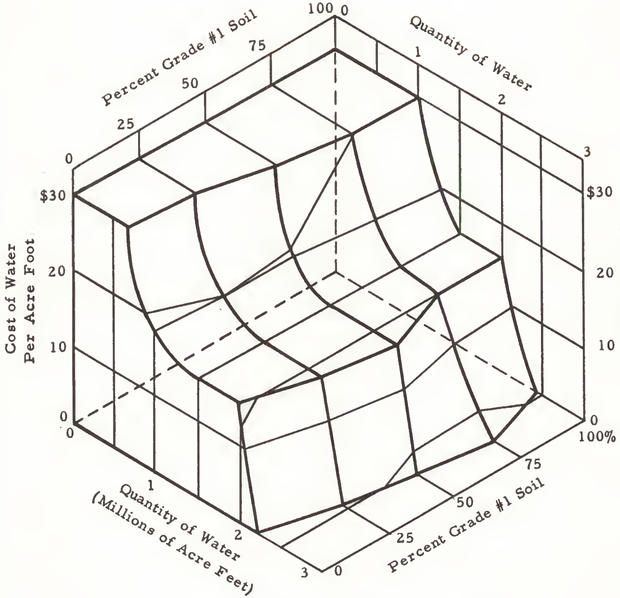
1/ The soil proportions are as follows: 100 percent Grade I; 0 Grade II; 70 percent Grade I, 30 percent Grade II; 50 percent Grade I, 50 percent Grade II; 25 percent Grade I, 75 percent Grade II; 0 percent Grade I, 100 percent Grade II.

Figure 5



Short Run Demand Surface For Irrigation Water, Cash Crop Farms Tulare County - Two Soil Grades

crop coming in to replace it, a large proportion of the land becomes idle when water costs reach this price level, even on the 100 percent Grade I soil (see Figure 5).

Several other observations are relevant from examining this demand surface. Irrigation water demand at lower prices is more elastic as the proportion of Grade I soil increases. This is evidenced by increasing over-all slopes for demand curves from left to right across the face of the demand surface. Maximum alfalfa acreage and, consequently maximum water use, occur at 70 percent Grade I and 30 percent Grade II soils, with water prices at zero. This use pattern reflects primarily, the absence of profitable alternative crops for the lower quality soil. A direct result of this disadvantage is that high water prices react more severely on net farm returns for those farmers operating units with a relatively high proportion of low quality soil, than for those with lower proportions.

Demand also becomes more elastic at water prices above $16.50 as the proportion of Grade I soil increases relative to that of Grade II. This tendency, recognizable from left to right, again reflects the lack of alternative low water-use crops that offer positive net returns-over-variable expenses at these higher water prices. Only cotton remains in production at the maximum water price ($30.00 per acre-foot) along the zero percent Grade I soil trace (see Figure 5).

These comments would be incomplete without recognizing the short-term aspects of this analysis in its usefulness for irrigation project planning and resource development. Because it is short term in nature, it provides only an indication of long-run demand for irrigation water, the most important aspect of demand in project planning. We also emphasize that the results of this analysis apply only to cotton-general crop farms in the relatively small geographic area studied; these results cannot safely be generalized to include fruit operations in all of Tulare County, nor to another geographic area with dissimilar physical and institutional restraints.

INTRAFIRM AND EXTERNAL CONDITIONS AND FORCES JOINTLY REGULATE AGGREGATE PRODUCTION RESPONSE TO VARYING COTTON LINT PRICES

The possibility that crops presently grown, or others yet to be introduced on most farms, may provide increased revenue to strengthen operator demand for irrigation water, represents an important consideration when exploring the agricultural future for the San Joaquin Valley Eastside. Cotton, presently the highest ranking crop in earnings on most farms, and the specialty crop group,

many of which compete closely with cotton on farms where they are grown, suggest themselves for some examination in this connection. Studies already cited indicate that the specialty crops are likely to expand within the study area. It would appear, therefore, that a continuation of production cost and product selling price relationships for these and other alternative crops in Eastside will be accompanied by some gains in farm net returns-over-variable costs, not considering irrigation water. Such gains should operate to support a somewhat stronger demand for irrigation water in the study area.

But what does the future hold for cotton production, prices, and net returns? Here, again, the Dean and McCorkle study suggests that important production increases may develop over the period of years up to about 1975. How might such gains affect farmer demand for irrigation water? One approach that may yield tentative answers to these questions is to prepare estimates of the production response (supply) schedule and curve for cotton lint. We undertook such an analysis, using linear programming methods, and beginning with data for individual farm models representing five general crop farms in the San Joaquin Valley Eastside.

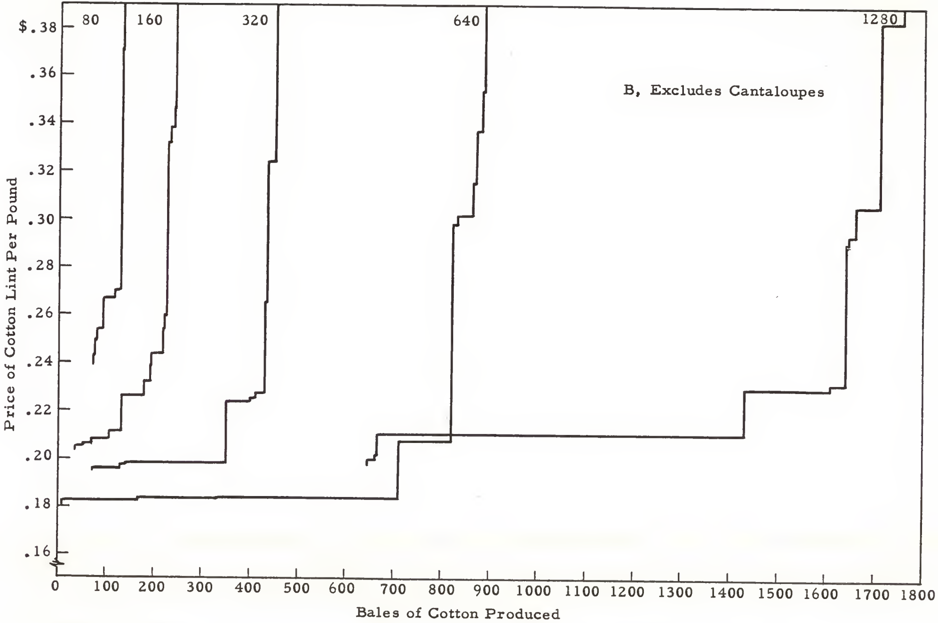
Operators Can Profitably Increase Cotton Production as Lint Prices Rise

Cotton, the dominant general field crop in San Joaquin Valley Eastside, lends itself well to an analysis of how price increases affect production response. The linear programming model used for each farm size in this analysis is based upon cropping System B, including in addition to cotton, sugar beets, blackeye beans, alfalfa, and feed grains. Standard conditions and assumptions already specified also apply in this analytical model.

Our approach, in exploring the impact of increasing cotton lint prices on production response, was to permit cotton prices to vary from zero to about 40 cents per pound of lint. Each of the resulting optimum solutions, according to total farm net returns-over-variable expenses, indicate a combination of cotton price and quantity produced, in bales. These price-quantity combinations, in turn, establish the production response schedule; when plotted, they appear as stepped production response curves (see Figure 6). Static-normative supply response data obtained in this manner for each of the five farm sizes show no cotton produced at lint prices less than 18.0 cents per pound. At this price level, and under conditions of this study, operators on 640-acre System B farms should include cotton in their cropping programs to maximize net returns-over-variable expenses. Two necessary conditions identify this lint price at which cotton will thus

Figure 6

Cotton Production at Varying Lint Prices
Five Farm Sizes



Source: Table

displace acres in some other crop and increase farm returns: first, gross receipts from an acre of cotton must exceed total variable expenses; second, the dollar magnitude of the returns-over-variable expenses for an acre of cotton must exceed those from the least profitable crop already included in the program.

For the other four analytical models in this study, the cotton lint prices that meet these two essential conditions are as follows: 80, 160, 320, and 1,280 acres, respectively; 23.9 cents, 20.3 cents, 19.4 cents, and 19.8 cents per pound (see Figure 6).

Production response continues to be sharp for relatively slight cotton lint price increases up to about 25 cents per pound. At this price level the percentage of crop land in cotton, according to 80- to 1,280-acre farm sizes, is as follows: 44.6 percent, 63.3 percent, 62.9 percent, 60.6 percent, and 59.0 percent, respectively. Slight additional increases are evident for lint price gains from 25 to 33 cents per pound. Only minor cotton acreage response follows, however, as lint prices rise above 33 cents for any of the five farm sizes.

Some of the basic conditions and assumptions specified in this study are important in establishing approximately two-thirds of the available crop land as the practical ceiling for cotton acreage on each of various farm sizes. The study frame-work as projected, assumes that farm resources and fixed costs remain unchanged, regardless of the farm cropping program. Irrigation water quantities available represent one of the fixed resources within this general frame-work. But irrigation water supplies represent one of the important constraints in the analysis; additional water, and therefore expanded facilities and increased capital investments and costs, would be necessary before operators could increase cotton production appreciably above a level representing about two-thirds of the crop land. We recognize, too, that other restrictions quite possibly would become evident if this water quantity constraint were lifted. Operator cropping programs prior to acreage allotments would appear to suggest that this is true. It was unusual for a farmer to plant more than about two-thirds of his available land to cotton.

We can disregard as not critical to our purposes in this analysis, the question of precisely how much additional production response to increased cotton lint prices might result if analytical models were modified to eliminate all restraints. The clear and consistent evidence obtained by analyzing the five farm size models under conditions of this study is sufficient for our purposes. It establishes definitely that, without price supports or acreage restrictions,

farmers would find it profitable to expand cotton production at prices above 18 cents per pound of lint. At decidedly less than recent support price levels, cotton would displace enough acres from other alternative crops to occupy two-thirds or more of the available acreage on most Eastside general crop farms.

Aggregate Production Responses May React Unfavorably Upon Individual Farm Profit Opportunities

In production response, as in demand, aggregate adjustments are important. The results of such aggregate shifts may react upon individual operators through the marketing and price structure so as to modify their profit opportunities sharply. Such a result can accompany joint action by a large proportion of all producers for a nationally marketed commodity when they shift in the same direction. This same principle applies in area analysis, providing the area studied produces a relatively important share of the entire production for the particular product. Ordinarily a relatively small geographic area, such as the one in this study, would be able to exert but a relatively small influence in the total national market for a product such as cotton. If, however, as assumed earlier in analyzing cotton production response under free market conditions, governmental price supports and acreage restrictions are lifted for the study area, they would be lifted for all other producers in major cotton-producing regions of the United States. It is relevant, therefore, to prepare estimates for the aggregate quantities of cotton that all farms in this study area would produce, assuming no governmental price support or acreage allotments.

For this purpose, we summed individual supply curves for the five farm sizes previously considered into a single area production response curve (see Figure 7). The procedure for aggregating these supply curves for five farm sizes into a study area total very closely parallels that used earlier in estimating aggregate demand for irrigation water (see Figure 3). The relative weight of each farm size aggregate supply response curve, again, is determined by the proportion that farms of this size represented in the total for all Tulare County farms holding ASC cotton acreage allotment contracts in 1954.[1/] We multiplied the quantities of cotton produced at each lint price along the stepped supply schedule by total farms for each of the five farm sizes and summed the resulting cotton quantities to obtain an aggregate short-run supply schedule for the 2,644 cash crop farms of 20 acres or more crop land with cotton allotments in Tulare County during 1954. This method admittedly provides only an approximation of cotton production response that

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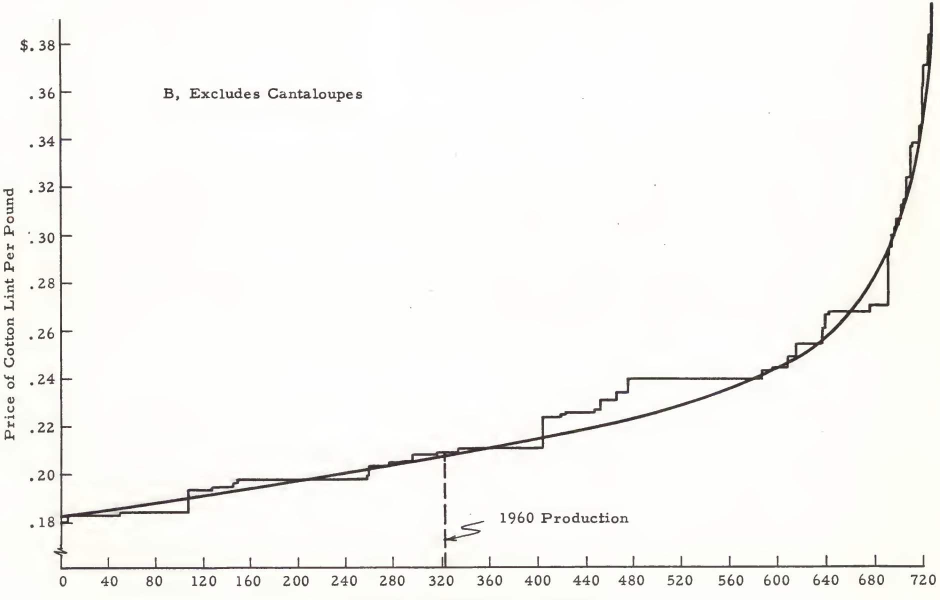
1/ Hedges, <u>loc. cit.</u>

Figure 7

Aggregate Shortrun Supply Response For Cotton Lint
Cash Crop Farms, Tulare County; No Acreage Controls



Source: Table

actually would occur if all cotton income supports and acreage allotment requirements were removed. Thus, it assumes that growers, without exception, will change their cropping programs to maximize farm net returns and profits. Again, this procedure ignores the fact that many small farms with cotton allotments also include acreages of perennial crops such as trees or vines, and, therefore, include limited amounts of land available for expanding cotton acreage. It is most unlikely that such growers would remove orchards and vineyards in order to increase cotton production if they could be assured of an earnings advantage for this crop only for one or a few years. Most of these cotton-growing fruit farms have relatively small cotton acreages, however, and collectively, they introduce only a small error into these estimates. In spite of these limitations, we believe that the aggregate production response schedule determined through this method of aggregation merits thoughtful attention.

Aggregate supply response data for the study area, when plotted, reflects the steps found in the individual curves for each of the five farm sizes, but these steps are less accentuated, and the curve is considerably smoother (see Figures 6 and 7). A freehand curve superimposed on the stepped response curve indicates approximately the continuous aggregate price-quantity relationship for cotton lint in the study area as farmers increase production in response to rising cotton prices.

Tulare County cotton production should almost double, according to these data, if price supports and acreage allotments were removed in the United States and California, and if cotton prices adjusted to world level. Thus at 24 cents per pound of lint, representing approximately the world price of California cotton, county production would be about 570,000 bales, as compared with slightly over 320,000 in 1960 (see Figure 7).

Under the conditions and assumptions of this study, farmers on a 640-acre farm size would find it profitable to replace other crop acreage with cotton when lint prices reach about 18 cents per pound. Then relatively small price gains above the 18-cent level would stimulate similar shifts for operators on the other four farm sizes. Aggregate cotton production response for price gains from 18.0 to 21.5 cents per pound would represent about a 12 percent increase in cotton production for each one percent gain in cotton lint prices (see Figure 7). Later production increases, following these sharp initial responses become progressively smaller. Thus for lint price rises from 21.5 to 24.5 cents per pound only 3.2 percent increase in cotton production should accompany each one percent price gain.

Corresponding responses at still higher prices are: from 24.5 to 28.5 cents--0.84 percent production increase, from 28.5 to 34.0 cents--0.30 percent production increase for each one percent of price increase. Thus the supply elasticity for cotton production response to changing cotton prices, as measured along the supply curve (coefficients of elasticity) becomes progressively smaller as cotton prices rise. The range is from 2.0 for price gains from 18.0 to 21.5 cents per pound, to only 0.30 for cotton lint price increases from 28.5 to 34.0 cents per pound. These cotton supply elasticities agree closely with those Nerlove found, for increases within higher cotton price ranges, for the pre-acreage allotment years 1909 through 1932.[1/] These results, based on the only recent extended period without cotton acreage allotments, showed cotton supply elasticity to be 0.67.

Data available for this analysis strongly indicate that cotton production would increase sharply if price supports and acreage allotments were terminated. Such results are quite consistent with the over-all cost, price, and net returns interrelationships between cotton and other alternative field crops in the study area and in the Southern San Joaquin Valley.

Cotton ranks sharply higher in earning capacity than any of these other crops, except some of the specialty products. But in general these specialty crops, individually or collectively, do not represent real alternatives for most farmers. Limited market outlets, special handling, selling contracts, specialized equipment, additional capital, or other resource needs, interfere to limit the number of farmers who successfully can include one or more of these other relatively high gross and net returns crops, along with cotton, in their farming systems. Thus, most farmers find themselves limited for practical purposes to cotton, representing relatively high gross and net returns per acre under effective income support and acreage allotment policies, on the one hand, and alfalfa plus feed grains, on the other. Products in the latter group rank sharply below cotton in earning capacity. These facts explain why cotton would continue to dominate most field crop farm cropping systems, even if lint prices were to drop sharply, under current short-term conditions, providing no acreage allotments or other restrictions were in force to interfere with farmers' planting decisions.

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1/ Nerlove, Marc, "Estimates of the Elasticities of Supply for Selected Farm Commodities," Journal of Farm Economics, May 1956, Volume 38:2, p. 505.

Over time, two forces would operate to lessen this dominance of cotton in the study area, and in much of the cotton-growing section of the San Joaquin Valley. We mentioned earlier the possibility, as indicated in the Dean and McCorkle report, that in the future specialty crops may be expected to expand acreage and production. If this happens, and if the earning capacity of these crops relative to cotton on a per-acre basis continues to be competitive, increasing numbers of farmers can consider a wider range of alternative crops in planning their cropping systems.

Another force, tending to have the same results but not adequately examined in this report, hinges on the likelihood that alfalfa and some of the other feed crops also may become somewhat stronger competitors of cotton for irrigated land in the study area and in the Southern San Joaquin Valley. Both the lower cotton lint prices, almost certain under any adjustment of United States and California prices to world market conditions, and whatever price strength might accrue to alfalfa hay and other feed crops, as a result of cotton absorbing some of the acreage in alfalfa under conditions of this study, would tend to narrow the relatively wide earnings advantage of cotton, and to increase the attractiveness of other crops to farmers in the area. These forces and tendencies, to the extent they materialize over time, will tend to lessen the sharpness of acreage and production response by cotton under free market production and price conditions for this crop. A recent analysis based on the Los Angeles hay market indicated that a 10 percent reduction in supply would cause an 18 percent increase in price. Given enough time, of course, the same forces will express themselves to a lesser extent in making both specialty and feed crops more competitive with cotton, even under cotton income support and acreage allotment conditions.

CONCLUSIONS

This report undertakes to answer two questions for cotton-general crop farms in Tulare County: first, how do increases in water price (variable costs) affect the rate of change in quantities used, as prices rise (the slope of the aggregate demand curve)? Second, how do increases in cotton lint prices affect the rate of change in production, as prices rise (the slope of the aggregate supply response curve)? The calculated aggregate water demand, and cotton supply response curves that resulted from our analysis appear meaningful, as a first approximation of the true demand and supply curves. Thus they should be useful to policy makers, water resource planners, those responsible for managerial decisions in individual firms, particularly farmers, and to the general public.

The static-normative aggregate demand curves fitted in this study indicate a sharp impact of water prices on quantities that farmers should buy (demand elasticities) in order to maximize total farm net returns and profits. Depending upon the price level for this resource (one percent rise in water price brought 0.19 decrease in water purchases at the zero through $16.50, and 0.70 percent decrease at the $16.50 through $30.00 per acre-foot price range). Public officials and managers in private firms should observe these data with care. They indicate that reduced total revenues to water development projects and distributors may result if prices to farmers are set too high. Thus in this study the highest total revenue to distributors accompanies the $16.50 per acre-foot price for irrigation water. Two other points are important: first, with fixed assessments for an area, the maximum quantities of water used will occur at zero price (variable costs); second, an irrigation district or mutual water company seeking only to cover costs can set metered prices lower, and deliver more water, than a private firm seeking maximum profits.

Certain conclusions also are indicated by the static-normative aggregate cotton supply response curve. Farmers almost certainly would expand cotton acreage and production sharply if federal price supports and acreage allotments were withdrawn. Under free market conditions, with California prices for cotton lint near the world market, production quite likely would double, but farm net returns would be about the same as at present (export payments were 6.0 cents per pound in 1960-61 and 8.5 cents per pound in 1961-62). This is evident from the relatively high supply elasticities as cotton lint prices varied in the analysis from 18.0 to 24.5 cents per pound. Cotton is the most profitable generally-grown crop in the study area, even without the relatively high price support level.

But under existing conditions farmers cannot look to cotton for any further large increases in their total farm net returns and profits, or alternatively, any increases in their ability to pay for irrigation water. Their best hopes for such gains lie in expanding markets with prices remaining at present levels, or declining less than the market expands. Another possibility may arise in growing demand and broadened production opportunities for other (chiefly specialty) crops, as some researches have indicated may occur by 1975.

Finally, those interested in the technical aspects of demand and supply analysis should find interesting the manner in which rigid constraints on managerial decisions and economic forces combined with physical conditions to cause the benched effect and to make two discrete curves necessary in fitting smooth curves to the aggregate water demand data. These data add further evidence to indicate how such artificial elements as price supports and acreage allotments operate to modify free market conditions and to distort resource use patterns that otherwise would exist. Under price supports, cotton has a sharp competitive advantage over alfalfa and other alternative crops, and remains profitable on the Grade I soil at irrigation water prices that make it impossible for the other general field crops to cover all variable expenses, particularly on the Grade II soil.

We believe that a procedure based on aggregating comprehensive data for the predominant farming system in a defined area, as applied in this study, offers the best available guides to planners and decision makers concerned with resource development, e.g., irrigation water storage and distribution facilities.

APPENDIX

APPENDIX TABLE 2

Variations in Net Returns-Over-Variable Expenses and Irrigation Water Variable Cost, Five Farm Sizes

80 acres

A a/ Returns	A a/ Irr. water	A a/ Cost/ ac.-ft.	B b/ Returns	B b/ Irr. water	B b/ Cost/ ac.-ft.	C c/ Returns	C c/ Irr. water	C c/ Cost/ ac.-ft.
dollars	acre-feet	dollars	dollars	acre-feet	dollars	dollars	acre-feet	dollars
11,739	380	0	10,369	410	0	10,045	382	0
9,749	351	5.23	8,221	340	5.23	8,044	344	5.23
9,551	348	5.80	6,089	337	11.51	4,184	294	16.45
9,892	347	10.56	4,368	197	16.61	4,140	155	16.61
7,563	320	11.51	3,301	155	22.02	2,084	150	29.86
6,620	309	14.40	2,084	150	29.85			
5,951	189	16.61						
5,347	181	19.81						
3,527	176	29.85						

160 acres

A a/ Returns	A a/ Irr. water	A a/ Cost/ ac.-ft.	B b/ Returns	B b/ Irr. water	B b/ Cost/ ac.-ft.	C c/ Returns	C c/ Irr. water	C c/ Cost/ ac.-ft.
dollars	acre-feet	dollars	dollars	acre-feet	dollars	dollars	acre-feet	dollars
24,805	728	0	24,310	779	0	23,579	731	0
20,870	696	5.40	20,550	662	4.82	23,118	730	.64
17,150	645	10.74	20,169	630	5.40	22,365	713	1.66
16,550	644	11.68	16,796	622	10.74	20,648	641	4.07
15,400	618	13.45	14,769	605	14.00	20,164	635	4.82
13,655	378	16.27	13,530	586	16.06	14,500	619	13.74
12,079	360	20.45	13,339	460	16.27	12,926	473	16.27
8,690	351	29.87	10,568	381	22.43	12,840	381	16.46
			7,730	372	29.88	7,730	370	29.87

320 acres

A a/ Returns	A a/ Irr. water	A a/ Cost/ ac.-ft.	B b/ Returns	B b/ Irr. water	B b/ Cost/ ac.-ft.	C c/ Returns	C c/ Irr. water	C c/ Cost/ ac.-ft.
52,948	1,519	0	47,810	1,655	0	46,919	1,614	0
41,437	1,519	7.57	35,256	1,654	7.57	34,692	1,613	7.57
38,851	1,465	9.28	32,430	1,360	9.28	33,180	1,599	8.51
38,236	1,401	9.70	27,538	1,342	12.88	33,010	1,458	8.62
34,051	1,377	12.68	26,914	1,339	13.33	32,049	1,375	9.28
33,746	1,350	12.90	26,620	1,338	13.56	21,880	805	16.67
33,517	1,331	13.07	22,737	1,200	16.45	19,239	620	19.94
33,432	1,210	13.14	22,483	813	16.67	13,160	599	29.75
29,154	964	16.67	22,022	779	17.23			
28,608	759	17.23	16,623	620	24.17			
25,075	720	21.89	13,159	599	29.75			
19,414	703	29.75						

640 acres

A a/ Returns	A a/ Irr. water	A a/ Cost/ ac.-ft.	B b/ Returns	B b/ Irr. water	B b/ Cost/ ac.-ft.	C c/ Returns	C c/ Irr. water	C c/ Cost/ ac.-ft.
108,403	3,050	0	95,205	3,232	0	92,076	3,065	0
98,134	3,007	3.36	86,215	3,205	2.76	84,793	2,837	2.40
96,238	2,807	3.96	84,320	2,727	3.36	83,627	2,833	2.76
75,105	2,650	11.52	61,630	2,689	11.64	81,972	2,762	3.36
74,009	2,457	11.88	50,004	2,374	15.96	47,061	2,746	15.96
63,425	1,951	16.20	49,452	1,628	16.20	46,421	1,616	16.20
61,768	1,926	17.04	48,068	1,626	17.04	46,205	1,241	16.32
59,617	1,502	18.24	46,253	1,566	18.24	29,515	1,198	29.88
53,666	1,443	22.08	35,003	1,241	25.44			
42,558	1,408	29.88	29,515	1,198	29.88			

1,280 acres

A a/ Returns	A a/ Irr. water	A a/ Cost/ ac.-ft.	B b/ Returns	B b/ Irr. water	B b/ Cost/ ac.-ft.	C c/ Returns	C c/ Irr. water	C c/ Cost/ ac.-ft.
233,119	6,101	0	210,373	6,460	0	200,583	6,129	0
171,320	6,017	10.13	146,138	6,406	9.94	143,080	5,673	9.37
167,827	5,615	10.70	144,889	5,453	10.13	139,909	5,666	9.94
118,501	5,180	19.49	93,303	5,371	19.58	138,817	5,523	10.13
117,355	4,866	19.70	89,607	4,729	20.27	82,787	5,492	20.26
113,239	3,853	20.56	88,264	3,250	20.56	81,228	3,233	20.56
108,421	3,337	21.80	84,198	3,194	21.80	80,983	2,482	20.63
98,699	2,886	24.72	74,889	3,125	24.72	58,171	2,397	29.82
83,966	2,817	29.82	58,928	3,041	29.82			
			55,361	2,396	30.99			

a/ A. Includes all Alternative Crops.
B. Excludes Cantaloupes.
C. Excludes Cantaloupes and Sugar Beets.

APPENDIX TABLE 1

Net Returns-Over-Variable Expenses Per Acre[a/] for Two Soil Types by Crop and Irrigation Treatment, Five Farm Sizes

Crop	Irr. treat-ment	80 acres						160 acres						320 acres					
		Chino soil			Traver soil			Chino soil			Traver soil			Chino soil			Traver soil		
		Gross receipts	Variable expenses	Net returns	Gross receipts	Variable expenses	Net returns	Gross receipts	Variable expenses	Net returns	Gross receipts	Variable expenses	Net returns	Gross receipts	Variable expenses	Net returns	Gross receipts	Variable expenses	Net returns
		dollars																	
Alfalfa hay	80-100	--	--	--	197	113	84	--	--	--	197	115	82	--	--	--	197	113	84
Alfalfa hay	80	195	112	88	201	114	87	195	112	83	201	114	87	195	111	84	201	114	87
Alfalfa hay	100	184	109	75	194	112	82	184	109	75	194	112	82	184	109	75	194	112	82
Barley	--	68	54	14	61	52	8	68	57	11	61	56	5	68	53	15	61	53	8
Barley/G. S.	80	168	117	51	164	127	37	168	117	51	164	130	34	168	112	56	164	124	40
Barley/G. S.	100	162	114	48	161	125	36	162	114	48	161	125	36	162	109	52	161	120	39
B. eyed beans	80-100	168	98	69	--	--	--	168	96	72	--	--	--	168	93	75	--	--	--
B. eyed beans	80	174	100	74	144	98	46	174	98	76	144	97	47	174	95	79	144	93	51
B. eyed beans	100	163	96	67	138	95	43	163	95	68	138	93	45	163	91	72	138	89	49
Cantaloupes	80	730	515	215	676	496	180	730	513	217	676	494	182	730	505	225	676	485	191
Cantaloupes	100	684	489	195	650	477	173	684	487	197	650	475	175	684	479	205	650	467	183
Cotton	60	420	229	191	--	--	--	420	198	222	--	--	--	420	186	234	--	--	--
Cotton	80	411	226	185	363	218	145	411	196	215	362	193	169	411	184	227	363	181	182
Cotton	100	383	217	166	348	212	136	383	191	192	348	189	159	383	178	205	348	177	171
Grain sorghum	80	100	65	35	103	78	25	100	63	37	103	77	27	100	63	37	103	76	27
Grain sorghum	100	94	62	32				94	61	33	--	--	--	94	61	33	--	--	--
Sugar beets	80	306	205	101	--	--	--	306	203	103	--	--	--	306	194	112	--	--	--
Sugar beets	100	287	201	86	--	--	--	287	199	87	--	--	--	287	190	97	--	--	--

Crop	Irr. treat-ment	640 acres						1,280 acres					
		Chino soil			Traver soil			Chino soil			Traver soil		
		Gross receipts	Variable expenses	Net returns	Gross receipts	Variable expenses	Net returns	Gross receipts	Variable expenses	Net returns	Gross receipts	Variable expenses	Net returns
Alfalfa hay	80-100	--	--	--	197	112	85	--	--	--	197	89	108
Alfalfa hay	80	195	112	83	201	115	86	195	86	109	201	90	112
Alfalfa hay	100	184	109	75	194	110	84	184	85	99	194	89	105
Barley	--	68	49	19	61	49	12	68	44	24	61	44	17
Barley/G. S.	80	168	106	62	--	--	--	168	95	73	--	--	--
Barley/G. S.	100	162	103	59	160	113	47	162	92	69	160	103	57
B. eyed beans	80-100	168	91	77	--	--	--	168	91	77	--	--	--
B. eyed beans	80	174	93	81	144	91	53	174	93	81	144	92	51
B. eyed beans	100	163	89	74	138	89	49	163	89	74	138	89	49
Cantaloupes	80	730	498	232	676	478	198	730	498	232	676	478	198
Cantaloupes	100	684	472	212	650	460	190	684	472	212	650	460	190
Cotton	60	420	171	249	--	--	--	420	171	249	--	--	--
Cotton	80	411	169	242	363	166	197	411	169	242	363	166	197
Cotton	100	383	163	220	348	162	186	383	163	220	348	162	186
Grain sorghum	80	100	60	40	--	--	--	100	51	49	--	--	--
Grain sorghum	100	94	58	36	99	67	32	94	50	44	99	59	40
Sugar beets	80	306	188	118	--	--	--	306	158	148	--	--	--
Sugar beets	100	287	183	104	--	--	--	287	156	131	--	--	--

a/ Gross receipts less variable expenses. Water at $3.00 per acre foot.

APPENDIX TABLE 3

Variations in Net Returns-Over-Variable Expenses and Cotton Production
Under Varying Cotton Lint Prices, Five Farm Sizes

B. Excludes cantaloupes														
80 Acres			160 Acres			320 Acres			640 Acres			1,280 Acres		
Returns	Cotton lint	Lint price	Returns	Cotton lint	Lint price	Returns	Cotton lint	Lint price	Returns	Cotton lint	Lint price	Returns	Cotton lint	Lint price
dollars	bales	per lb.	dollars	bales	per lb.	dollars	bales	per lb.	dollars	bales	per lb.	dollars	bales	per lb.
7,913	0	0	12,452	0	0	25,933	0	0	51,973	0	0	132,438	0	0
7,913	71	.239	12,452	34	.203	25,933	70	.194	51,973	4	.180	132,438	645	.198
8,050	76	.243	12,490	50	.205	25,976	128	.195	52,047	332	.183	133,049	659	.200
8,290	79	.249	12,498	66	.206	26,087	143	.197	52,171	712	.184	133,700	662	.202
8,495	92	.254	12,500	67	.206	26,171	348	.198	60,616	807	.208	136,737	1,424	.211
9,075	114	.267	12,628	104	.209	30,619	398	.224	73,944	823	.240	150,619	1,611	.231
9,251	124	.270	12,696	132	.211	30,781	412	.225	97,783	829	.298	151,316	1,641	.232
12,001	125	.314	13,713	177	.226	31,262	429	.227	98,385	856	.300	200,479	1,646	.292
13,543	126	.339	14,427	190	.234	39,667	434	.266	99,470	864	.302	202,211	1,660	.294
15,581	128	.371	14,894	191	.239	52,133	447	.324	105,158	867	.315	212,736	1,712	.306
			15,395	216	.244	60,731	447	.362	114,551	881	.337	278,428	1,757	.383
			16,414	219	.254									
			17,208	224	.261									
			25,145	226	.332									
			25,870	235	.338									
			26,687	236	.345									

APPENDIX TABLE 4

Irrigation Water Added to Soil, Irrigation Efficiency, and Total Seasonal Applications by Soils, Irrigation Practices, and Crops, Five Farm Sizes

Crop	Depletion levels for available soil moisture											
	(1) 100 percent			(2) 80 percent			(3) 80-100 percent			(4) 60 percent		
	Water added	Effi-ciency a/	Total water	Water added	Effi-ciency a/	Total water	Water added	Effi-ciency a/	Total water	Water added	Effi-ciency a/	Total water
	inches	percent	inches	inches	percent	inches	inches	percent	inches	inches	percent	inches
A. Chino clay loam												
Cotton	30.2	64.6	46.8	34.0	64.5	52.7				33.5	62.3	53.7
Cantaloup	19.4	63.5	30.6	22.0	62.3	35.3						
Sugar beets	38.7	61.8	62.6	40.2	63.3	63.5	42.0	62.6	67.1			
Alfalfa (estab.)	35.3	63.2	55.9									
Alfalfa	51.5	66.0	78.0	52.7	66.0	79.9	52.8	66.0	80.0			
Field corn	23.0	64.8	35.6	27.4	62.3	43.9	23.8	63.7	37.3			
Grain sorghum	20.4	62.6	32.5	22.9	61.6	37.3	25.6	61.9	41.4			
Grain Sorghum (late)	20.4	62.3	32.7	22.9	61.6	37.2						
B. Traver fine sandy loam												
Cotton	29.1	56.7	51.3	28.9	51.5	56.2				29.2	43.0	67.9
Cantaloup	18.9	48.9	38.7	22.4	47.1	47.6						
Beans (black-eyed)	14.6	47.8	30.7	14.6	44.8	32.5	14.1	47.1	29.9			
Alfalfa (estab.)	30.7	55.1	55.8									
Alfalfa	50.8	64.2	79.1	52.6	63.6	82.7	52.0	64.2	81.0			
Field corn	24.4	56.7	43.0	27.9	53.1	52.6	24.2	56.0	43.1			
Grain sorghum	19.5	49.5	39.4	23.0	47.6	48.3	20.9	48.0	43.5			
Grain sorghum (late)	19.5	49.5	39.4	23.0	47.6	48.3						

a/ Irrigation efficiencies are seasonal weighted averages of individual water applications.

Division of Agricultural Sciences

UNIVERSITY OF CALIFORNIA

ECONOMICS OF ON-FARM IRRIGATION WATER AVAILABILITY AND COSTS, AND RELATED FARM ADJUSTMENTS

2. Farm Size in Relation to Resource Use, Earnings, and Adjustments on the San Joaquin Valley Eastside

Charles V. Moore and Trimble R. Hedges

CALIFORNIA AGRICULTURAL EXPERIMENT STATION
GIANNINI FOUNDATION OF AGRICULTURAL ECONOMICS

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FOREWORD

This is analytical report number 2 in the series of investigations under California Agricultural Experiment Station Project Numbers 1641 and H-1863. Titles of these projects indicate their objectives and subject matter; Economics of Adjustments on California Cotton Farms, and Effects of On-Farm Irrigation Water Supplies and Costs on Cropping Systems and Production Adjustments. The latter-named project is partially supported by funds allocated for that purpose by the University of California Water Resources Center. It also is the California Agricultural Experiment Station supporting project under Western Regional Project Number W-70, Economics of On-Farm Use of Irrigation Water.

Other Experiment Station reports under the general series title for these irrigation investigations include: 1. Enterprise Choices, Resource Allocations, and Earnings on 640-Acre General Crop Farms in the San Joaquin Valley Eastside, 3. Some Aggregate Aspects of Farmer Demand for Irrigation Water and Production Response in the San Joaquin Valley Eastside, and 4. Subarea Variations in Relation to Resource Use, Earnings, and Adjustments in the San Joaquin Valley Cotton Area. Some Characteristics of Farm Irrigation Water Supplies in the San Joaquin Valley also has appeared as an Experiment Station release, as have various articles in California Agriculture. In addition, several articles in technical journals amplify various aspects of these investigations.

We are indebted to many agencies and individuals without whose generous cooperation neither this report nor others in the series would have been possible. Among these we can list only a few of those upon whom we relied most heavily. The major power companies serving the San Joaquin Valley, Pacific Gas and Electric, and Southern California Edison, authorized us to use well test data previously released to the United States Geological Survey. The latter agency aided greatly in this procedure by making photostatic copies from office records. The California Regional Water Pollution Control Board made well driller reports available to us (data for individual reports are not identified in order to keep both of these sets of information confidential). The California Department of Water Resources also assisted greatly in these studies by making maps, reports, and other information available,

as did the United States Bureau of Reclamation. The California Irrigation Districts Association, many individual irrigation districts, and various manufacturers and distributors of irrigation pumps and equipment provided much valuable assistance in the form of factual data and interpretation. We, of course, drew heavily on published reports and releases of the agencies named here, plus many others.

Among the many individuals to whom we owe appreciation, we wish to mention particularly Messrs. R. S. Ayers, W. Balch, D. E. Butler, J. S. Gorlinski, E. J. Griffith, H. H. Holley, G. V. Hufford, J. M. Ingles, F. Munz, B. M. Smith, H. M. Stafford, S. T. Stairs, L. Stennett, and H. D. Wilson. A complete list would extend to a much greater length; we stop at this point only because of space limitations, not for lack of awareness or appreciation of the assistance generously made available by many others.

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SUMMARY

This report, the second in a series resulting from investigations of on-farm irrigation economics, deals primarily with how farm size variations interact with changes in irrigation water quantities and costs to affect farm resource use and earnings. It, like the previous report, centers upon a study area in the San Joaquin Valley Eastside, and includes only Cotton-General Crop farms. Five synthesized farm size models analyzed (80-, 160-, 320-, 640-, and 1,280-acre units, respectively) represent the size groups including practically all the commercial cotton-growing farms in Tulare County during 1954, as indicated by County Agricultural Stabilization and Conservation Committee records. Their dominant characteristics, available resources, production organization patterns and methods, and input-output ratios are carefully specified according to modal tendencies for such data on farms in the study area. This is to make them as typical as possible of farms producing cotton and general crops in the Tulare County Eastside during the period 1956-1960.

Total farm fixed costs, averaging about $100 per acre for all five farm sizes, did not enter the first steps in this analysis, directed to determining optimum solutions under varying water costs and quantities available. These solutions, instead, reflect only variable inputs and expenses; fixed costs come into the total farm analysis later in order to evaluate total earnings and prepare profit and loss summaries. Considering variable inputs and expenses for two soil grades and three irrigation treatments, cotton provided highest net returns per acre for Grade I soil on all farm sizes except the 80-acre model. On this unit, cantaloups ranked first and second, with cotton third. Cantaloups out-ranked cotton in first place for Grade II soil on all farm sizes, however, and took the first two of three possible places for the three smaller farm sizes. Sugar beets and alfalfa hay occupy a somewhat middle position in the descending order according to net returns per acre for crops in the study area, with grain crops at the lower levels.

By expanding farm size and/or adding other high net-returns-per-acre crops, farmers on these units may expect to increase their ability to pay for irrigation water. An operator on a 1,280-acre farm under conditions of this study can break even in total farm net returns-over-variable expenses

-- vis-a-vis total farm fixed costs -- at variable water costs of $17 per acre-foot, whereas the operator on an 80-acre unit finds his break-even ceiling price for water at about $7.50 per acre-foot. On each of these farm sizes, the grower with the "A" range of alternative crops is the one in the strongest earnings position; as compared with System C crops, the 1,280-acre unit producing A alternatives indicates break-even capacity at $17.00 versus $11.60, per acre-foot. For the 80-acre size, the comparative water prices at break-even levels for total farm net returns-over-variable costs are $7.50 for System A and $3.50 for B.

As water prices rise, farmers adjust quantities used by a series of reasonably definite steps. These reductions in water use for the total farm operation follow a common pattern for all size models, a "stepped" demand curve in which relatively sharp decreases in water taken accompany each price rise. Competition among crops, based upon relative costs, outputs, net returns, and total water requirements, determines the regularity of these several steps. The sequence of possible adjustments available to farmers as water prices rise is reasonably clear, however; first, they shift to drier treatments on existing crops; second, they reduce acreage for the higher-use crops and allocate the water to those with lower requirements; third, they leave less-productive land idle; fourth, they idle portions of the better land, planting only more profitable crops; fifth, they cease farming and go out of business when water costs continuously preclude profitable operations on the best land with the highest return crops.

Farm size also sharply affects how variations in quantities of water available react on water use, cropping programs, and farm earnings. Thus a single 1,280-acre farm has about $32,000 greater net returns-over-variable costs than the total for sixteen 80-acre units at 2,400 acre-feet, and $37,000 at 4,800 acre-feet of irrigation water as the total available for the season (with fixed costs per acre at approximately the same level). Again, as for varying water prices, the more high-gross-returns crops available as alternatives, the greater the net returns; for the 1,280-acre farm the System A group shows an advantage of about $18,000 over B and C at 2,400 acre-feet, and about $27,000 and $33,000 over B and C systems, respectively, at 4,800 acre-feet.

Similar shifts in crops and acreages associated with optimum returns as available water quantities vary were evident for all five analytical models. Crops enter the farming program for the B group of alternative crops in the following order as water quantities increase; cotton, blackeye beans, sugar beets, and alfalfa. In general, farmers will obtain optimum returns if they begin with the drier irrigation treatments, then shift to the wetter ones as more water becomes available. Value of additional production for the initial water increments begins at levels at or near the $80 per acre-foot level, depending on farm size, with A alternative crops. They decline steadily with successive additions, until they drop below $7 for the final increments. The same pattern of declining value for additional production holds for the other two groups of alternative crops, but initial net returns are lower for all farm sizes with these crop choices.

In spite of certain limitations in the data, this study shows clear-cut evidence of how economies arise as farm size increases from 80 to 1,280 acres. Average total costs per unit of product, using total farm revenues to represent output for these multi-product firms, are entirely consistent with the theoretical framework developed by economists to explain economies of scale. Declining average total costs per unit apply to each farm size as production expands within the short-run period to capacity limits set; these several curves for farms of progressively larger sizes fit together smoothly within the over-all envelope curve suggesting the longer-run adjustment patterns. Most of the cost savings per unit due to increasing size appear in comparing the three smaller sized farms, but profit advantages accrue as size increases throughout the entire range for all five models. Increased output volume is important here as well as savings per unit. These data, again, show the advantages to farmers in higher earnings potentials if they can choose from a range of alternatives including two or more high gross and net returns crops when planning their cropping programs.

Farm profits, both in dollars and as rates earned on average total farm capital investments, reflect the earnings advantages of increasing farm size under conditions of this study. Actual dollars returned as capital and management income more than double as size doubles from the 80- to the 160-acre farm, and so, consecutively, for each successive pair of size models. Thus the profit (return to capital and management) is $2,500 for the 80-, and $10,200 for the 160-acre farm. Approximate totals for the other three sizes

are as follows: 320-, $22,100; 640-, $48,700; and 1,280-acre, $108,250. Interest earned on average total investment in all farm property for the five analytical models was 3.8 percent, 8.2 percent, 8.8 percent, 9.6 percent, and 10.5 percent, respectively for the sizes ranging from 80 to 1,280 acres. Imputed management income ranged from -$1,364 for the 80- to $46,955 for the 1,280-acre farm.

Cotton is the dominant source of gross and net returns for all farm sizes and all three sets of alternative crops (cropping systems) considering both acres planted and performance per acre. An important question to farmers deciding water use policies, therefore, is, "What are my opportunities for growing cotton profitably?" An analysis assuming that the federal price supports and acreage allotments no longer apply, but that other conditions and restrictions included in the study framework still pertain, clearly indicates that cotton would expand greatly in both acres and lint production if such conditions did prevail. Farmers on 80-acre farms should plant no cotton at lint prices less than 23.9 cents per pound, while those on the other farm sizes should bring cotton into their programs at prices varying from 18.0 to 20.3 cents per pound of lint. Cotton would occupy about 60 percent of all cropland on the four larger models and almost half of that on the 80-acre farm at 25.0 cents per pound; at 33.0 cents these proportions should increase to two-thirds on the larger four units and three-fourths on the smaller one. Break-even prices for cotton lint accompanying such production would be at prices ranging from 21.6 cents per pound for the 640- and 1,280-acre models to 27.0 cents for the 80-acre unit, with irrigation water variable costs at $3 per acre-foot. Break-even total farm net returns-over-variable costs would be at sharply higher cotton prices if water variable expenses were higher; for example, at 30.0 cents per pound for the 80-acre farm with water costs at $9 per acre-foot.

Clearly, farmers in the San Joaquin Valley Eastside would greatly increase cotton production in the absence of acreage allotments. The supply response tendencies for all farm sizes studied indicate that if both allotments and price supports were absent, farmers in this subarea might double the proportion of their cropland planted to cotton, recognizing that prices easily might adjust to about 25.0 cents per pound of lint, roughly the world price level in 1961 for cotton of quality approximating the California crop. This question of aggregate response, as well as that of aggregate demand for irrigation water, is considered more fully, and specifically in a companion report.

ECONOMICS OF ON-FARM IRRIGATION WATER AVAILABILITY AND COSTS AND RELATED FARM ADJUSTMENTS

2. Farm Size in Relation to Resource Use, Earnings, and Adjustments on the San Joaquin Valley Eastside

Charles V. Moore and Trimble R. Hedges 1/

This study undertakes to identify and measure the relation of farm size to how irrigation water supplies and costs affect resource use and earnings on individual farms. The first report in this series, based on studies of on-farm irrigation economics, centered on problems relating to quantities and cost of irrigation water on a 640-acre farm model in the San Joaquin Valley Eastside. 2/ It investigated how variations in quantities of irrigation water available, and in the cost for such water, relate to water use, optimum cropping programs, and farm earnings under such programs, and to production adjustments in Tulare County on the San Joaquin Valley Eastside. This present report also examines the same group of basic economic questions concerning irrigation and its effects on farm organization, adjustments, and profits in the same study area (see Figure 1). It expands the scope and emphasis of the analysis, however, to examine farm size as an important characteristic that interacts with, and complicates the effects of variations in irrigation water quantities and costs on farm organization and earnings.

Such an analysis is necessary because farm size variations do react sharply on other characteristics of farm businesses. These variations set definite limits on the possibilities of generalizing the results of a study based on one specific farm size to different sized units. Critically important characteristics that vary according to size include physical, economic,

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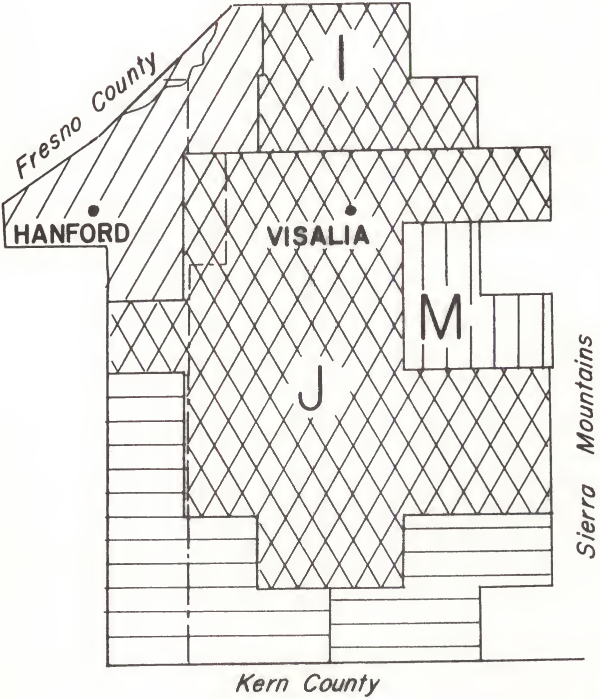
2/ Hedges, Trimble R., and Charles V. Moore, Economics of On-Farm Irrigation Water Availability and Costs, and Related Farm Adjustments. 1. Enterprise Choices, Resource Allocations, and Earnings on 640-Acre General Crop Farms in the San Joaquin Valley Eastside, Calif. Agr. Expt. Sta., Giannini Foundation, Res. Report. No. 257, Davis: 1962.

Figure 1

STUDY AREA

Modal Pump Lift by Geographic Area, San Joaquin Valley, 1949-54



and institutional phenomena. Some of the more important examples are machinery and equipment size and capacity in relation to annual use requirements, volume and timing of purchases and consequent bargaining leverage in relation to prices for goods and services used in production, marketing effectiveness in relation to sales prices for farm products, input requirements of farm enterprises for management, and the general problem of internal efficiency based on combining and using resources effectively. Important items among this wide range of characteristics express their influence differently according to farm size by affecting input costs and prices per unit of product -- and ultimately, net returns per output unit -- and profits for the entire farm. These variations also react upon the opportunities for farm adjustments to relative changes in prices and costs, and to the methods that are effective in achieving such adjustments.

This Study Had Seven Specific Objectives

The analyses reported here examine in detail how variations in irrigation water quantities and costs react on farm characteristics that help to regulate profitable operation. Their approach and emphasis, however, center upon the interrelationships of farm size variations upon these important irrigation questions.

Seven specific objectives must be met in order to achieve the over-all goals specified above: (1) Determine farm models typical of predominant cotton-general crop farm sizes in the study area (five farm sizes were selected for this purpose). (2) Establish the physical characteristics of farm irrigation water supplies, including both underground and surface sources; determine how these characteristics relate to water costs, including both fixed and variable components, as these costs change with farm size. (3) Construct complete crop budgets, including all production materials and services, for each farm size selected; determine total revenue, aggregate variable expenses, and net returns-over-variable expenses for each alternative crop; relate these basic facts to relevant resource, economic, and institutional conditions for each of the five farm models. (4) Determine the effects of a wide range of variations in total annual water quantities on optimum cropping programs, resource allocations, and adjustments, and on-farm earnings for each of analytical models.

(5) Measure the effects of a wide range of variations in water costs on water use, optimum cropping programs, resource allocations and adjustments, and farm earnings on the farm models. (6) Identify and evaluate how variations in farm size affect short-run production costs; estimate the approximate long-run average total cost curves in relation to farm size adjustments. (7) Identify and measure how cotton lint price variations over a wide range react on optimum water use, cropping programs, resource allocations, cotton production, and farm earnings for each of the farm size models.

Appropriate Procedures Were Necessary for Each Specific Objective

1. Determine Farm Size Models.--Data obtained through the cooperation of the California and Tulare County Agricultural Stabilization and Conservation Service and the Agricultural Extension Service in an earlier study provided the basic background used to select farm sizes for analysis (Objective 1).1/ The Eastside county had 3,952 cotton allotment contracts in 1954,(the most recent complete tabulation), of which 1,308 were 20 acres or less in size. Of the remaining 2,644 allotments, 1,566 or 59.2 percent, represented units of 21 to 100 acres, with the others distributed over four size ranges, as follows:

101 - 220 acres	554 farms	21.0 percent
221 - 420 acres	301 farms	11.4 percent
421 - 940 acres	172 farms	6.5 percent
941 acres and over	51 farms	1.9 percent

We selected five farm sizes, 80-, 160-, 320-, 640-, and 1,280-acres, respectively, as analytical models. These are intended to represent as closely as is practicable the major size groups in the farm distribution for cotton-general crop farms as determined by the earlier study. Some of the 1954 allotments in Tulare County went to operators who also produce fruit, either tree or vine, and therefore are not free to allocate all cropland to annual crops. It is evident, also, that some changes in numbers by farm sizes occurred between 1954 and the date of this study, due to land transfers, shifting tenure arrangements, and other causes. We recognize these limitations in the Tulare

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1/ Hedges, Trimble R., Economic Adjustments on California Cotton Farms, Preliminary Statistical Summary No. 1, Calif. Agr. Expt.Sta.,Giannini Foundation unnumbered Mimeo. Report, Davis: 1955.

County farm data as used for determining the five sizes used in this analysis. It appears, however, that such changes as have occurred have not seriously altered the over-all size distribution for Tulare County farms; these five sizes are still dominant.[1/] Analysis and findings relating to these sizes, therefore, should provide useful indications of how size variations affect irrigation economics on cotton-general crop farms in Tulare County. Units with cotton allotments of 20 acres or less, largely representing small open land acreages on fruit farms, part-time farms, or other special conditions, are omitted because they are too small for an economic unit in cotton-general crop farming, as will be evident in examining earnings data for the five sizes included here.

2. Establish Farm Irrigation Water Supply Characteristics.--Earlier analyses based on power company well tests, well driller reports, Irrigation District and other water distributor data, precipitation records, and interviews with farmers and service agency representatives enabled us to establish farm irrigation supply characteristics. The actual data used represent summaries of this wide range of information and are intended so far as possible to typify actual water quantity and cost conditions on farms in the study area.[2/]

3. Construct Crop Budgets by Farm Sizes.--Budgeting methods served effectively to establish acre performance data for the various crops. Calendars of operations, physical input schedules, related yields, and price and cost data were necessary for building these budgets. Completed crop budgets include summary data for all variable input expenses, gross receipts, and net returns-over-variable expenses for each crop under each irrigation treatment for each farm size. These data show net returns both with and without irrigation water costs considered.

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1/ Tulare County farms reporting cotton numbered 2,413 in 1959 according to the United States census. See U.S. Census of Agriculture 1959, Vol. II, Chap. 5, U.S. Department of Commerce. Although not strictly comparable with the earlier A.S.C. data, the Census figures on numbers of cotton growing farms according to size indicate that the distribution in 1959 was similar to that in 1954.

2/ Hedges, Trimble R., and Charles V. Moore, "Irrigation Pumping Plant Characteristics in the San Joaquin Valley," California Agriculture, Vol. 14, No. 8, August 1960, pp. 2 and 3.

Moore, Charles V., and Trimble R. Hedges, "Irrigation Costs of Pumping in the San Joaquin Valley," California Agriculture, Vol. 14, No. 10, October 1960, pp. 3 and 4.

Ibid., "Water Deliveries and Costs in the San Joaquin Valley Cotton Area," Vol. 15, No. 3, March 1961, pp. 7 and 8.

More complete information regarding these procedures appears in the first report of this series, dealing with the 640-acre farm size.[1] How to establish the effects of irrigation practices for the various crops on yields, according to soil characteristics, was a critical problem in this procedure. The basic concept applied is that amounts of soil moisture available to plants directly affect growth rates and yields, but that such available moisture varies invesely with mean moisture stress (tension) in the soil. Thus as the quantity of moisture in the soil decreases from field capacity (FC) to the permanent wilting percentage (PWP), tnesion rises, and progressively less is available to plants.[2] We emphasized three irrigation practices with estimated yields for each in applying this concept, identifying each practice according to the percentage of available soil moisture depleted prior to irrigation. These practices were as follows: "dry treatment" (No. 1), 100 percent depletion; "medium treatment" (No. 2), 80 percent depletion; "wet treatment" (No. 4), 60 percent depletion. In addition a "mixed treatment" (No. 3) is used for some crops on certain soils. Yields, costs per acre for water, application, and various inputs related to yield, and net returns per acre varied among the crops and soils studied according to these four irrigation practices.

4. and 5. Evaluate How Variations in Irrigation Water Quantities and Costs Affect Farm Performance.--Linear programming was the analytical tool used to determine how variations in total annual quantities of water available, and in water prices, affect optimum water use, cropping programs and resource allocations, adjustments, and farm earnings. This procedure involved determining optimum solutions for each of the three cropping alternatives for each of five farm sizes, according to prescribed ranges of variation in water quantities, water variable costs, and cotton lint prices.[3] [4] [5]

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1/ Hedges and Moore, Economics of On-Farm Irrigation Water Availability and Costs and Related Farm Adjustments. 1. Enterprise Choices, . . . , pp. 22-24, and Appendix.

2/ Hedges and Moore, Economics of On-Farm Irrigation Water Availability and Costs and Related Farm Adjustments. 1. Enterprise Choices, . . . , pp. 24-36, and Appendix. See also citations appended.

3/ Ibid., pp. 37-41, and Appendix.

4/ Heady, Earl O., and Wilfred Candler, Linear Programming Methods, Iowa State College Press, Ames, Iowa: 1958.

5/ Garvin, Walter W., Introduction to Linear Programming, McGraw-Hill Book Company, New York: 1960.

6. Determine Short-Run Average Total Cost Curves.--Linear programming also was the basic procedure for this portion of the study. Total farm revenue, net returns, and all variable expenses for each optimum solution within the established restrictions, resulted from this analysis. By combining fixed costs with these variable expense totals, it was possible to calculate average total costs, and costs per dollar of revenue, at each solution. These latter data identified the least-cost combination, and, when plotted, established the short-run total average cost curves for each farm size.

7. Measure the Effect of Cotton Lint Price Variations.--We examined how variations in cotton lint prices affect cotton production, farm resource allocations and adjustments, and total farm net returns again using linear programming. This procedure parallels that used in the first report, previously cited above.

FIVE SYNTHESIZED MODELS TYPIFY CONDITIONS ON FARMS IN THE STUDY AREA

Farm Model Characteristics Are Based on Detailed Facts About the Study Area 1/

Data were obtained from both primary and secondary sources. Interviewers visited farmers in the study area to obtain facts on production organization

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1/ Major terms relating to farm models appearing in this report, and their definitions, are as follows:

Cropping System -- detailed cropping organization for a Farm Model.
Farm Model -- synthesized Farming System, based on modal farm characteristic data for a particular geographic subarea.
Farming System -- detailed organization, methods of operation, and practices used on a Farm Model (see Appendix Tables 2 and 3).
Subarea -- a segment of a major geographic area, such as the San Joaquin Valley, selected for study.
Irrigation Practice -- technique or method used in irrigation, identified in this study by the depletion level for available soil moisture prior to irrigation.
Variable Expenses (Costs) -- sum of annual cash operating expenses, plus unpaid family (operator's) labor. (See Appendix Tables 3 through 5.) This item may appear as Variable Expenses (Costs) per Acre for a single crop, or as Farm Variable Expenses (Costs) representing the total for an entire farm.
Fixed Costs -- sum of annual cash and noncash costs for using capital items and for general costs not readily allocated to specific enterprises.
Gross Receipts -- sum of annual receipts from sales of farm crops.
Net Returns-Over-Variable Expenses (Costs) -- Gross Receipts minus Variable Expenses. (Costs) (see Appendix Tables 4 and 5). This item may appear as Net Returns-Over-Variable Expenses (Costs) for a single crop acre, or as Farm Net Returns-Over-Variable Expenses (Costs) representing the total for an entire farm.

(Continued on next page.)

according to the various farm sizes, and farm service agencies to collect information on production materials and services, marketing practices, services, and costs, and other relevant data. Information from farmers included basic organizational and operational data: farm acreages by use; irrigation facilities, quantities of water available and seasonal timing; specific power, machinery, and equipment items and dollars invested in each; irrigation and other production practices; extent of dependence upon custom or rental services, their sources, and costs; overhead requirements and costs not readily assigned to individual enterprises. Farmer service agencies supplied price and cost information, much information on materials and practices used in production and marketing farm products, and important assistance in preparing estimates for crop acreages, yields, and other aspects of Tulare County agriculture.

University of California researchers and Agricultural Extension workers, as well as scientists and technicians in the United States Department of Agriculture, the Geological Survey, and other federal agencies, and in the California Department of Water Resources and other State divisions, supplied much valuable information, particularly on the over-all water supply situation in the study area and the fundamental factors affecting it.

The first major task in the analysis under this study was to synthesize the five farm models used for this purpose. The procedure in this synthesis was to specify the major characteristics of each farm size, according to the information outlined above, with the aim of assuring that each model accurately reflects modal tendencies in these characteristics for the comparable farms in the study area. Similarly, production technology, farm practices, calendars of operation, and other aspects of farm operation are specified to typify conditions and operations in the study area.

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1/ (Continued from previous page.)

Net Farm Income -- Net Cash income plus (or minus) inventory changes on noncapital items and minus noncash fixed costs (not including interest on investment). Any unpaid labor contributed by the farm operator is not included in the farm expenses.

Profit (Capital and Management Income) -- Net Farm Income minus the value of any unpaid labor (including operator's).

Management Income -- Profit less 6 percent on the total farm capital. The residual (and it may well be negative) is payment for the operator's managerial ability and services.

Rate Earned -- Profit (Capital and Management Income) expressed as a percentage of the farm capital.

1. Soil and Water Resources.--Basic physical determinants remain in the same proportions for each of the five farm sizes analyzed. Farmland is classified as 70 percent Chino clay loam (Grade I) and 30 percent Traver fine sandy loam (Grade II) soil. Both underground and surface sources contribute to the total quantities available, which vary from month to month. Thus underground, or pumped water quantities vary from 7.97 gallons per minute per acre in the spring months to 7.6 gallons at mid-season, to 7.06 gallons in the late summer. To such quantities are added available surface supplies: .073 acre-feet per acre in March, .088 in April, .304 in May, and .089 in June.

2. Power, Machinery, and Labor.--Rates of accomplishment for different sized pieces of equipment and variations in the amount of work to be done explain wide differences between machinery lines among the five farm sizes. Machinery and equipment inventories for each farm model essentially are for row-crop agriculture, although some provision is made for hay and small grains (see Table 1). At the two extremes, equipment inventories for the 80-acre farm include no harvesting equipment other than a mower and rake, while the 1,280-acre unit is fully equipped to harvest all crops grown. The latter size includes a hay baler, combine, and sugar beet digger. All farms larger than the 80-acre unit include cotton harvesters adequate to meet farm requirements. This analysis makes no provision for off-farm contract operations by workers and equipment on any of these five analytical models; thus all use and related costs for the equipment inventories are identified with the respective farm models.

A resident farm labor force is indicated for each of the five farm sizes (see Table 1). Additional labor needed during peak seasons is provided through part-time or seasonal employees, at a standard rate of $1.25 per hour.

3. Crops, Acreage, Limitations, and Cropping Systems.--Crops considered in this analysis are those most commonly found on farms in the San Joaquin Valley Eastside: cotton, cantaloups, sugar beets, alfalfa hay, grain sorghum (milo), blackeye beans, and barley. In addition to these seven possible components of a cropping system, a barley-grain sorghum double cropped combination represents an eighth enterprise. Among these eight possible enterprises, cotton, alfalfa hay, and barley are the most common, cantaloups definitely represent a speciality crop, grown by relatively few producers,

TABLE 1

Farm Real Estste, Operating Equipment, Investments, and Permanent Labor Supply, Five Farm Sizes

Item	80 acres			160 acres			320 acres			640 acres			1,280 acres		
	Size	Number	Avg. invest. dollars	Size	Number	Avg. invest. dollars	Size	Number	Avg. invest. dollars	Size	Number	Avg. invest. dollars	Size	Number	Avg. invest. dollars
Land															
Raw land	$500/A	80A	40,000	$500/A	160A	80,000	$500/A	320A	160,000	$500/A	640A	320,000	$500/A	1,280A	640,000
Cost of leveling	$100/A		8,000	$100/A		16,000	$100/A		32,000	$100/A		64,000	$100/A		128,000
TOTAL			48,000			96,000			192,000	$600/A		384,000	$600/A		768,000
Improvements															
Tractor shed		1	250		1	375		1	625		1	625		1	1,000
Storage and shop		1	625		1	750		1	1,000		2	2,000		1	2,500
Fuel storage															
Gas	350 gal.	1	55		1	68	550 gal.	1	67	550 gal.	1	67	1,000 gal.	1	125
Diesel	550 gal.	1	67				550 gal.		67	550 gal.	1	67	1,000 gal.	1	100
Grain storage													500 T	1	2,500
Shop equipment						100			375			500			750
Labor housing							2 bdrms.	1	4,000	2 bdrms.	3	12,000	2 bdrms.	7	28,000
TOTAL			997			1,293			6,134			15,259			34,975
Irrigation															
Pumps				20 HP	1	1,562	45 HP	2	5,275						
Pumps	30 HP	1	2,398	30 HP	1	2,398	20 HP	1	1,562	45 HP	5	13,187	45 HP	10	26,375
Wells	16" x 678'	1	4,833	16" x 678'	1	4,833	16" x 678'	2	9,776	678'	5	24,415	678'	10	48,830
Wells				12" x 410'	1	1,418	12" x 410'	1	1,418						
Pipeline	14"	1,320'	673	14"	2,640	1,346	16"	5,280'	2,851	14"	10,560	4,910	14"	21,120	9,821
Pipelines										18"	6,600	4,389	18"	13,200	8,778
Stands	8' x 36"	1	28	8' x 36"	2	56	8' x 36"	4	85	36"	8	276	36"	16	451
Vents	8' x 8"	2	18	8' x 8"	4	36	8' x 8"	4	36	5"	24	206	5"	48	413
Alfalfa valves	10"	10	77	10"	20	155	10"	40	310	14"	248	3,900	14"	496	7,799
Siphons	2" x 3"	75	75	2" x 3"	150	150	2" x 3"	300	300	2"	600	600	2"	1,200	1,200
Irrig. improve			1,623			2,304			4,047			8,448			17,384
TOTAL			9,725			14,258			25,660			60,331			121,051
REAL PROPERTY TOTALS			58,722			111,551			223,794			459,590			924,026
Power															
Tracklayer							D-4	1	5,840	70 HP	1	9,781	110	1	12,760
Tracklayer													45	1	6,273
Wheel tractor	25 HP	1 (used)	912	25 HP	1	1,460	25 HP	2	3,060	35 HP	3	5,762	35	3	4,720
Wheel tractor	35 HP	1	1,715	35 HP	2	3,565	35 HP	2	3,705	25 HP	2	3,147	25	6	11,525
Transportation															
Pickup	3/4 T	1	1,314	3/4 T	1	1,375	3/4 T	2	2,990	3/4 T	3	4,660	3/4 T	5	7,767
Trucks										1-1/2 T	1	2,081	1-1/2 T	2	4,004
TOTAL			3,941			6,400			15,595			25,431			47,049
Trailers															
Low-bed												250		1	250
Equipment												250		2	500
Cotton	5-bale	2	600	5-bale	3	900	5-bale	6	1,800	5-bale	6	1,800	5-bale	10	3,000
Fuel and service														1	100
Machinery															
Landplane										10' x 40'	1	1,350	12' x 60'	1	1,800
Scraper	5'	1	75	6'	1	75	10'	1	375	10'	1	375	10'	1	375
Ditcher	4'	1	175	2'	1	88	5'	1	200	54"	1	200	5'	2	400
Subsoiler										2-shank	1	700	3-shank	1	1,050
Chisel							8'	1	325	12'	1	600	12'	2	1,200
Plow, 2-way, MB	2 - 16"	1	412	2 - 16"	1	412	2 - 16"	1	412	2 - 16"	1	412	4 - 18"	1	2,500
Disk plow													6 - 22"	1	625
Lister plow	2-row	1	90	2-row	1	112	4-row	1	112	4-row	1	113	4-row	2	225
Disks	8' sec.	1	400	7' 6"	1	400	12'	1	700	18'	1	1,025	18'	1	1,025
Disks										7-1/2'	1	400	12'	1	700
Cultipackers	10'	1	200	12"	1	250	12'	1	250	20'	1	437	20'	1	437
Cultipackers													14'	1	320
Spiketooth harrow	4' sec.	3	60	4'	4	75	4'	6	120	4'	8	125	4'	12	240
Border disk					1	112		1	112		1	112		1	112
Planter	2-row	1	250	4-row	1	500	4-row	1	500	4-row	1	500	4-row	2	1,000
Cultivators	2-row	1	225	4-row	1	437	4-row	2	875	4-row	2	875	4-row	4	1,750
Stalk cutter				2-row	1	338	2-row	1	337	2-row	1	338	4-row	1	600
Grain drill										10'	1	400	12'	1	500
Mower	7'	1	238	7'	1	238	7'	1	237	7'	1	237	7'	2	475
Rake, SD	8'	1	320	8'	1	320	8'	1	320	8'	1	320	8'	2	640
Cotton picker				1-row (used)	1	1,750	1-row	1	4,950	2-row	1	10,045	2-row	2	20,900
Combine													12'	1	4,200
Baler													3-wire	1	3,300
Bale loader													-	1	325
Grain elevator													30'	1	350
Sugar beet harvester														1	2,117
TOTAL			3,045			6,007			11,625			20,864			51,016
Power, transportation, and machinery															
TOTAL			6,986			12,407			27,220			45,795			98,065
ALL PROPERTY TOTALS			67,708			123,958			251,014			505,885			1,022,091
Permanent labor force															
Operator		1			1			1			1				1
Foreman															1
Full-time labor								1			3				7

NOTE: Differences in average investment for the same machine on different size farms is due to the assumptions used concerning average life and salvage value.

while sugar beets and blackeye beans occasionally appear in cropping plans. We include cantaloups to represent high net return crops as a group; no one of the several possible alternatives in this group accounts for a sizeable acreage in Tulare County. A number of field crops are subject to government or other acreage limitations. Thus acreage allotments under the price support programs limit cotton to about 33 percent of the cropland; a restriction exists during some years for sugar beets. Considering this fact, plus rotational requirements in the interest of pest control, sugar beet acreage in this study is limited to a maximum of 12 percent of the cropland. Special problems and arrangements in marketing for cantaloups, and concerning the breadth of the market and price tendencies for blackeye beans are recognized in this study by arbitrary upper limits for these two crops at 15 and 35 percent, respectively, of cropland.

We also deemed it necessary in this study to recognize the more important variations among farms in the study area in the range of alternative crops and the combinations of these within which farm operators must plan their cropping programs. Thus we grouped these eight alternative enterprises into three different sets of alternative crops:

A. Includes all alternative crops.

B. Excludes cantaloups.

C. Excludes cantaloups and sugar beets. Later references to this classification designate the three sets of alternative crops as cropping systems A, B, and C, or as cropping alternatives A, B, and C.

Detailed analyses for each of the five models, directed towards major objectives of this study, include optimum solutions under varying conditions for each of these three alternative systems. This analytical approach should contribute importantly to increasing the range of application of results, from the individual farm viewpoint.

4. Crop Yields and Irrigation Practices.--Yields occupy an important place in the economics of profitable irrigated farming. It was necessary for purposes of this analysis to obtain the most realistic yields possible for each of the several crops for each applicable combination of soil and irrigation practice for each farm model. These estimated yields reflect a combination of available experimental results and considered judgments by resource and extension workers in the fields of irrigation and related plant sciences. The same yield pattern applies to each of the five farm sizes.

Actual yields selected for each of the soil-crop-irrigation treatment combinations represent a percentage of an estimated potential yield that can be expected from a specified irrigation practice on that particular soil. The detailed explanation of methods used in preparing these estimates appears in the first report in this series.1/

Total Farm Fixed Costs Average About $100 per Acre

Fixed costs include both cash and noncash items (see Table 1). The principal items in the first category are ad valorem taxes on farm property, insurance premiums, demand charges on irrigation pumps,2/ and irrigation district assessments. Other cash fixed costs include such items as social security and workmen's compensation insurance premiums on employees, office, accounting, and other overhead managerial expenses, plus any hired supervisory personnel, not charged directly to production enterprises.

Depreciation on capital investments other than land (including outlays for leveling) and interest on average capital investments for all farm property are the principal noncash fixed costs items.3/

Total fixed costs for the five farm sizes in this study range from approximately $8,500 per year for the 80-acre unit, to $132,000 for the 1,280-acre farm (see Table 2). In comparison, the ratio of total fixed cost for these extreme sizes, at 15.6 to 1, is slightly lower than the average ratio (16 to 1). Both annual totals represent sizeable cost loads for the final net returns-over-variable expenses to cover before the operator can obtain returns for his own supervision, management, and risk assumption. The amounts, in dollars per acre, are approximately $106 for the 80-, vs. $103 for the 1,280-acre farm model.

We excluded fixed costs from the linear programming analysis in this study. We considered them and their effects after determining optimum solutions

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1/ Hedges and Moore, Economics of On-Farm Irrigation Water Availability and Costs and Related Farm Adjustments. 1. Enterprise Choices, . . . , pp. 33-36, and Appendix. See also Appendix Tables 4 and 5 this report.

2/ Some might question demand charges on irrigation pump motors as fixed costs, but this classification is appropriate for this study. These analyses are based on the farm models as going concerns; operators on such farming units commit themselves in advance for demand charges on pumping motors if power is connected.

3/ See Appendix Table 1 for methods used in calculating fixed costs on capital items.

TABLE 2

Summary of Fixed Costs, Five Farm Sizes

Item	80 acres			160 acres			320 acres			640 acres			1,280 acres		
	Non-cash	Cash	Total	Non-cash	Cash	Total	Non-cash	Cash	Total	Non-cash	Cash	Total	Non-cash	Cash	Total
	dollars														
Property															
Land	2,800	780	3,580	5,760	1,560	7,320	11,520	3,120	14,640	23,040	6,240	29,280	46,080	12,480	58,560
Labor housing							540	120	660	1,620	360	1,980	3,770	850	4,620
Other improvements	130	30	160	179	37	216	326	63	389	490	94	584	1,072	205	1,277
Irrigation (original)	1,430	185	1,615	2,083	273	2,356	3,716	492	4,208	8,579	1,196	9,775	17,156	2,357	19,513
Irrigation (added)	274	36	310	274	36	310	692	91	783	1,475	194	1,669	2,950	390	3,340
Machinery and equipment	1,721	258	1,979	3,404	414	3,818	7,086	933	8,019	12,181	1,674	13,885	25,287	3,313	28,600
Subtotal	6,355	1,289	7,644	11,700	2,320	14,020	23,880	4,819	28,699	47,385	9,758	57,143	96,315	19,595	115,910
General overhead															
Social Security and Workmens Compensation		131	131		262	262		545	545		1,360	1,360		2,283	2,283
Office, accounts, and dues		100	100		200	200		400	400		800	800		1,600	1,600
Irrigation demand charges		202	202		336	336		735	735		1,497	1,497		3,000	3,000
Irrigation districts assessments		400	400		800	800		1,600	1,600		3,200	3,700		6,400	6,400
Supervision														2,700	2,700
Subtotal		833	833		1,598	1,598		3,280	3,280		6,857	6,857		15,983	15,983
TOTAL	6,355	2,122	8,477	11,700	3,918	15,618	23,880	8,099	31,979	47,385	16,615	64,000	96,315	35,578	131,893

for maximizing total farms net returns-over-variable expenses. This approach assumes that the physical resources used in the farm business and related fixed costs will remain unchanged regardless of the shifts in costs, prices, cropping programs, and other resource use adjustments. Maximizing total net returns-over-variable expenses for the entire farm also will maximize farm earnings and profits in such a short-run period. It is possible under this method, by comparing total fixed costs with this total net returns value, to establish the "break-even" value for net returns that exactly covers total farm fixed costs. This break-even point itself, then, becomes an important yardstick in evaluating farm earnings performance. Farm profits and other earnings measures also are calculated, using total farm net returns-over-variable expenses and total farm fixed costs, in conjunction with imputed estimates for interest on capital and the value of the operator's labor at going market rates.

Alternative Crops Vary Widely in Gross Receipts, Variable Expenses, and Net Returns per Acre

Net returns-over-variable expenses for a single acre of a crop were critical for this study.1/ Our crop budgets covering the five farm sizes and the various crops on different soil types under four possible irrigation treatments, reveal wide variation in net returns per acre (see Table 3). Within the entire range of crops, cantaloups and cotton show the highest net returns-over-variable expenses, and barley the lowest for every farm size. On the Chino (Grade I) soil, cotton occupies two of the top three places, according to net returns per acre, for all size groups except the 80-acre unit, and these are first and second places for all sizes except the 160-acre model. Cantaloups show higher net returns than cotton on the Traver (Grade II) soil for all farm sizes. Thus cantaloups rank first and second among two cotton and two cantaloup irrigation treatments for the three smaller farm sizes and first and third for the 640- and 1,280-acre units. Sugar beets, although showing distinctly lower net returns per acre than the top-ranking two crops, are the next most profitable on the Chino soil for which they are adapted. Both irrigation treatments for this crop rank next in order after

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1/ See Appendix Tables 2 and 3 for detailed variable expense calculations, Appendix Tables 4 and 5 for net returns-over-variable expenses data.

TABLE 3

Net Returns Per Acre for Two Soil Types by Crop and Irrigation Treatment, Five Farm Sizes[a/]

Crop	Irr. treat-ment	80 acres						160 acres						320 acres					
		Chino soil			Traver soil			Chino soil			Traver soil			Chino soil			Traver soil		
		Gross receipts	Variable expenses	Net returns	Gross receipts	Variable expenses	Net returns	Gross receipts	Variable expenses	Net returns	Gross receipts	Variable expenses	Net returns	Gross receipts	Variable expenses	Net returns	Gross receipts	Variable expenses	Net returns
		dollars																	
Alfalfa hay	80-100	--	--	--	197	113	84	--	--	--	197	115	82	--	--	--	197	113	84
Alfalfa hay	80	195	112	88	201	114	87	195	112	83	201	114	87	195	111	84	201	114	87
Alfalfa hay	100	184	109	75	194	112	82	184	109	75	194	112	82	184	109	75	194	112	82
Barley	--	68	54	14	61	52	8	68	57	11	61	56	5	68	53	15	61	53	8
Barley/G. S.	80	168	117	51	164	127	37	168	117	51	164	130	34	168	112	56	164	124	40
Barley/G. S.	100	162	114	48	161	125	36	162	114	48	161	125	36	162	109	52	161	120	39
B. eyed beans	80-100	168	98	69	--	--	--	168	96	72	--	--	--	168	93	75	--	--	--
B. eyed beans	80	174	100	74	144	98	46	174	98	76	144	97	47	174	95	79	144	93	51
B. eyed beans	100	163	96	67	138	95	43	163	95	68	138	93	45	163	91	72	138	89	49
Cantaloups	80	730	515	215	676	496	180	730	513	217	676	494	182	730	505	225	676	485	191
Cantaloups	100	684	489	195	650	477	173	684	487	197	650	475	175	684	479	205	650	467	183
Cotton	60	420	229	191	--	--	--	420	198	222	--	--	--	420	186	234	--	--	--
Cotton	80	411	226	185	363	218	145	411	196	215	362	193	169	411	184	227	363	181	182
Cotton	100	383	217	166	348	212	136	383	191	192	348	189	159	383	178	205	348	177	171
Grain sorghum	80	100	65	35	103	78	25	100	63	37	103	77	27	100	63	37	103	76	27
Grain sorghum	100	94	62	32				94	61	33	--	--	--	94	61	33	--	--	--
Sugar beets	80	306	205	101	--	--	--	306	203	103	--	--	--	306	194	112	--	--	--
Sugar beets	100	287	201	86	--	--	--	287	199	87	--	--	--	287	190	97	--	--	--

Crop	Irr. treat-ment	640 acres						1,280 acres					
		Chino soil			Traver soil			Chino soil			Traver soil		
		Gross receipts	Variable expenses	Net returns	Gross receipts	Variable expenses	Net returns	Gross receipts	Variable expenses	Net returns	Gross receipts	Variable expenses	Net returns
Alfalfa hay	80-100	--	--	--	197	112	85	--	--	--	197	89	108
Alfalfa hay	80	195	112	83	201	115	86	195	86	109	201	90	112
Alfalfa hay	100	184	109	75	194	110	84	184	85	99	194	89	105
Barley	--	68	49	19	61	49	12	68	44	24	61	44	17
Barley/G. S.	80	168	106	62	--	--	--	168	95	73	--	--	--
Barley/G. S.	100	162	103	59	160	113	47	162	92	69	160	103	57
B. eyed beans	80-100	168	91	77	--	--	--	168	91	77	--	--	--
B. eyed beans	80	174	93	81	144	91	53	174	93	81	144	92	51
B. eyed beans	100	163	89	74	138	89	49	163	89	74	138	89	49
Cantaloups	80	730	498	232	676	478	198	730	498	232	676	478	198
Cantaloups	100	684	472	212	650	460	190	684	472	212	650	460	190
Cotton	60	420	171	249	--	--	--	420	171	249	--	--	--
Cotton	80	411	169	242	363	166	197	411	169	242	363	166	197
Cotton	100	383	163	220	348	162	186	383	163	220	348	162	186
Grain sorghum	80	100	60	40	--	--	--	100	51	49	--	--	--
Grain sorghum	100	94	58	36	99	67	32	94	50	44	99	59	40
Sugar beets	80	306	188	118	--	--	--	306	158	148	--	--	--
Sugar beets	100	287	183	104	--	--	--	287	156	131	--	--	--

a/ Gross receipts less variable expenses, water at $3.00 per acre-foot.

cotton and cantaloups for all five sizes except the 80-acre model, on which alfalfa hay displaces one sugar beet treatment in ranking order. Alfalfa hay and blackeye beans follow next in order after sugar beets, according to net returns, for all farm sizes, with alfalfa hay showing slightly greater net returns-over-variable expenses. In addition to barley, grain sorghum and barley-grain sorghum double-cropped combinations show sharply lower net returns than any of the other crops.

Yields, plus costs and prices per yield unit, are responsible for determining absolute and relative net returns per acre among these crops.1/ Irrigation water requirements per acre and variable expenses per acre-foot for this resource, in turn, exert important influence on changes in cost per acre, and per yield unit, for individual crops. This is why differences in quantities of water available, or in variable cost per acre-foot for available water, can cause changes in crop choices and in acreage allocations, among the range of alternative crops within a given cropping system.

VARIATIONS IN IRRIGATION WATER COSTS SHARPLY AFFECT FARM WATER USE, RESOURCE ALLOCATIONS, AND TOTAL FARM NET RETURNS

Water Cost Variations Stimulate Changes in Cropping Programs and Resource Allocations

A farm operator's demand for irrigation water arises from his belief that by using this resource he will be able to increase his profits. If this operator has full and accurate knowledge of relevant facts and relationships, he will limit the quantities that he is willing to purchase to those that he can obtain at prices consistent with his goal -- to maximize profits. He will undertake to regulate his water purchases by weighing the added cost of each additional quantity of water, e.g., an acre-foot, against the added dollar return he expects to accrue if he does add that last unit. Other factors that a grower must consider in deciding expectations with respect to net returns include, weather, price, and yield uncertainties. He will govern his willingness to pay (say) three dollars to purchase and apply the last acre-foot of water according to whether or not he expects the sales value

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1/ See Appendix Table 4 for prices and yields used in this study.

of the product, added by applying this last acre-foot of water to equal three dollars or more. The cost for an additional increment of water (and/or other scarce resource) becomes highly critical in a manager's decisions regarding added water purchases and applications as water costs rise. A profit-seeking manager will not be willing to pay more dollars for this added quantity than he expects to realize from the resulting production.

It was important in this analysis to examine changes in production as irrigation water prices (variable costs) varied from zero to about $30 per acre-foot.1/ For this examination we calculated variable cost programming solutions for each of the five farm sizes studied.2/ The initial solution for each farm size at zero charge for irrigation water of variable expenses indicates optimum crop choices and resource allocations with water as a free resource (good). New combinations of crops, and different relative acreages become optimum as the price (variable cost) for water increases from zero to the $30 per acre-foot level. The result is a series of water quantity-price combinations, each of which represents an optimum solution under the specified conditions. The entire series for each farm size represents a "stepped" demand schedule. These steps are not uniform for any one farm size and are not necessarily parallel, among the give farm sizes (see Figure 2). Many variations appear in the relationship between change in price and quantity of water from one step to the next. One particular combination of crops and relative acreages may remain optimum over a relatively wide price range; another combination may be effective for only a very narrow price variation.

Fundamental biological and economic variations among crops, in how soils and climate affect crop performance and yield, and in production technology explain changes in cropping programs accompanying optimum solutions as water

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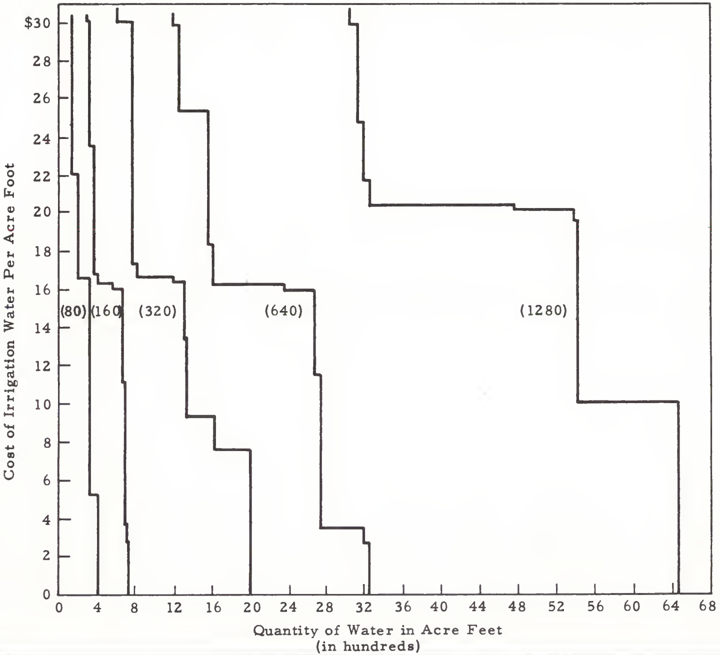
1/ A simple procedure will determine fixed and total costs for irrigation water at the pump head or farm gate, using appropriate estimates for irrigation water variable expenses. Annual fixed or overhead costs for pumping irrigation water under conditions of this study on the 640-acre general crop farms, for example, total $13,797 (these costs do not include allowances for farm distribution systems). The rate per acre-foot will vary inversely, according to the quantities pumped; at 3,000 acre-feet, the fixed cost per acre-foot is $4.60; at 2,500 this cost increases to $5.52; at 2,000 acre-feet, it reaches $6.90 per acre-foot; and at 1,500, $9.20 per acre-foot. Total water cost per acre-foot equals these fixed costs, plus outlays for irrigation water variable expenses. Thus at $3.00 per acre-foot for this latter item, total costs under the above range of fixed costs will vary from $7.60 to $12.20 per acre-foot. Similar estimates can be prepared for alternative quantities of water and for other levels of irrigation water variable expenses.

2/ Heady, Earl O., and W. Candler, op. cit., p. 758.

Figure 2

Farm Demand For Irrigation Water, Five Farm Sizes



prices vary. Farmers, acting in their own self interest in an effort to maximize farm net returns or profits, adjust to increasing irrigation water cost by a series of steps. First, they use drier irrigation treatments on the crops in their cropping programs, as long as this adjustment is effective in making the dollar returns to the last increment of water equal to the cost for this increment. Second, these farmers shift from heavy water-use crops to others with lower total water requirements. Third, when lower quality soils no longer are capable of returning gross receipts sufficiently high to cover variable expenses, operators leave this less productive land idle. Fourth, they will plant only the crops that are capable of paying for the higher priced water on even the higher grade land, leaving portions of this soil idle. Fifth, if water cost reaches such levels that even the highest net return crops on the most productive soils are unable to cover variable cost, farm operators will exercise their final adjustment; they will abandon farming and go out of business. This final drastic step usually will be taken only as a last resort, and after highly adverse conditions have existed for sometime. Characteristically, farm operators "use up their capital" and contribute their own and other family labor at little or no returns during this interim period before finally going out of business.[1/]

A careful examination reveals that operators on these various farm sizes reduce water use about equally in response to changes in water costs, although this may not be obvious at first glance from a comparison of the 80-, and 1,280-acre farm (see Figure 2 and Table 4). This relationship is more evident, however, after multiplying the length of each horizontal step for the 80-acrefarm demand schedule by 16 (1,280 divided by 80 = 16). All demand schedules feature

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1/ The initial report in this series includes a detailed analysis of how these steps operate on a 640-acre general crop farm in the San Joaquin Valley Eastside as farm operators adjust to successively higher water prices. This analysis shows crop choices and other land use, such as idle land and acreages in each, by soil grades for each of a series of five cropping programs adopted as water prices rise. This 640-acre model is the same as the one representing that size group in this analysis. Close similarities among these stepped demand schedules for this model and the other four sizes indicate that the above-cited five steps whereby farmers adjust to increasing water costs apply generally to all five farm sizes in this report. For actual data on the 640-acre model and more detailed analysis, see Hedges and Moore, Economics of On-Farm Irrigation Water Availability and Costs and Related Farm Adjustments. 1. Enterprise Choices, . . . , pp. 56-58.

TABLE 4

Variations in Gross Receipts Less Variable Expenses and Irrigation Water Variable Costs, Five Farm Sizes

80 acres

A a/			B b/			C c/		
Returns	Irr. water	Cost/ ac.-ft.	Returns	Irr. water	Cost/ ac.-ft.	Returns	Irr. water	Cost/ ac.-ft.
dollars	acre-feet	dollars	dollars	acre-feet	dollars	dollars	acre-feet	dollars
11,739	380	0	10,369	410	0	10,045	382	0
9,749	351	5.23	8,221	340	5.23	8,044	344	5.23
9,551	348	5.80	6,089	337	11.51	4,184	294	16.45
9,892	347	10.56	4,368	197	16.61	4,140	155	16.61
7,563	320	11.51	3,301	155	22.02	2,084	150	29.86
6,620	309	14.40	2,084	150	29.85			
5,951	189	16.61						
5,347	181	19.81						
3,527	176	29.85						

160 acres

A a/			B b/			C c/		
Returns	Irr. water	Cost/ ac.-ft.	Returns	Irr. water	Cost/ ac.-ft.	Returns	Irr. water	Cost/ ac.-ft.
dollars	acre-feet	dollars	dollars	acre-feet	dollars	dollars	acre-feet	dollars
24,805	728	0	24,310	779	0	23,579	731	0
20,870	696	5.40	20,550	662	4.82	23,118	730	.64
17,150	645	10.74	20,169	630	5.40	22,365	613	1.66
16,550	644	11.68	16,796	622	10.74	20,648	641	4.07
15,400	618	13.45	14,769	605	14.00	20,164	635	4.82
13,655	378	16.27	13,530	586	16.06	14,500	619	13.74
12,079	360	20.45	13,339	460	16.27	12,926	473	16.27
8,690	351	29.87	10,568	381	22.43	12,840	381	16.46
			7,730	372	29.88	7,730	370	29.87

320 acres

A a/			B b/			C c/		
Returns	Irr. water	Cost/ ac.-ft.	Returns	Irr. water	Cost/ ac.-ft.	Returns	Irr. water	Cost/ ac.-ft.
dollars	acre-feet	dollars	dollars	acre-feet	dollars	dollars	acre-feet	dollars
52,948	1,519	0	47,810	1,655	0	46,919	1,614	0
41,437	1,519	7.57	35,256	1,654	7.57	34,692	1,613	7.57
38,851	1,465	9.28	32,430	1,360	9.28	33,180	1,599	8.51
33,236	1,401	9.70	27,538	1,342	12.88	33,010	1,458	8.62
34,051	1,377	12.68	26,914	1,339	13.33	32,049	1,375	9.28
33,746	1,350	12.90	26,620	1,336	13.56	21,880	805	16.67
33,517	1,331	13.07	22,737	1,200	16.45	19,239	620	19.94
33,432	1,210	13.14	22,483	813	16.67	13,160	599	29.75
29,154	964	16.67	22,022	779	17.23			
28,608	759	17.23	16,623	620	24.17			
25,075	720	21.89	13,159	599	29.75			
19,414	703	29.75						

640 acres

A a/			B b/			C c/		
Returns	Irr. water	Cost/ ac.-ft.	Returns	Irr. water	Cost/ ac.-ft.	Returns	Irr. water	Cost/ ac.-ft.
dollars	acre-feet	dollars	dollars	acre-feet	dollars	dollars	acre-feet	dollars
108,403	3,050	0	95,205	3,232	00	92,076	3,065	0
98,134	3,007	3.36	86,215	3,205	2.76	84,793	2,837	2.40
96,238	2,807	3.96	84,320	2,727	3.36	83,627	2,833	2.76
75,105	2,650	11.52	61,630	2,689	11.64	81,972	2,762	3.36
74,009	2,457	11.88	50,004	2,374	15.96	47,061	2,746	15.96
63,425	1,951	16.20	49,452	1,628	16.20	46,421	1,616	16.20
61,768	1,926	17.04	48,068	1,626	17.04	46,205	1,241	16.32
59,617	1,502	18.24	46,253	1,566	18.24	29,515	1,198	29.88
53,666	1,443	22.08	35,003	1,241	25.44			
42,558	1,408	29.88	29,515	1,198	29.88			

1,280 acres

A a/			B b/			C c/		
Returns	Irr. water	Cost/ ac.-ft.	Returns	Irr. water	Cost/ ac.-ft.	Returns	Irr. water	Cost/ ac.-ft.
dollars	acre-feet	dollars	dollars	acre-feet	dollars	dollars	acre-feet	dollars
233,119	6,101	0	210,373	6,460	0	200,583	6,129	00
171,320	6,017	10.13	146,138	6,406	9.94	143,080	5,673	9.37
167,827	5,615	10.70	144,889	5,453	10.13	139,909	5,666	9.94
118,501	5,180	19.49	93,303	5,371	19.58	138,817	5,523	10.13
117,355	4,866	19.70	89,607	4,729	20.27	82,787	5,492	20.26
113,239	3,853	20.56	88,264	3,250	20.56	81,228	3,233	20.56
108,421	3,337	21.80	84,198	3,194	21.80	80,983	2,482	20.63
98,699	2,886	24.72	74,889	3,125	24.72	58,171	2,397	29.82
83,966	2,817	29.82	58,928	3,041	29.82			
			55,361	2,396	30.99			

a/ A. Includes all Alternative Crops.

b/ B. Excludes Cantaloups.

c/ C. Excludes Cantaloups and Sugar Beets.

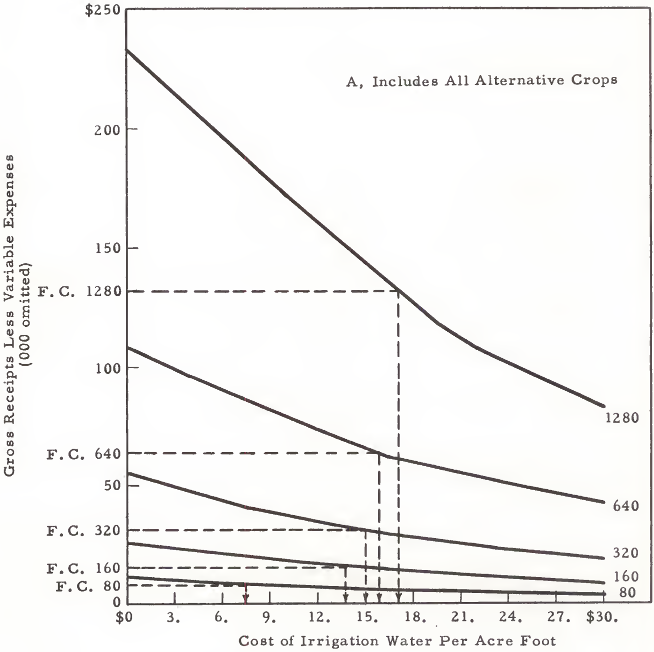
relatively short horizontal steps for price changes below the $16 per acre-foot water variable expense level. These reflect such adjustments as using drier irrigation treatments on crops already in the program, and shifting from high to low water-use crops in new programs. In contrast, the relatively long step for all farm models except the 1,280-acre at $16.50 per acre-foot occurs because a large portion of Traver soil (Grade II) is left idle at this cost level; gross receipts from alfalfa no longer cover variable expenses. Lower alfalfa harvesting costs on the largest farm delays this reaction until water variable expenses reach about $20.50 per acre-foot.

WATER COST VARIATIONS REACT STRONGLY ON TOTAL FARM NET RETURNS-OVER-VARIABLE EXPENSES AND PROFITS

Results of a linear programming analysis in which variable expenses for irrigation water increase over a range from zero to $30 per acre-foot reveal a decidedly close inverse relationship between irrigation water cost and total farm net returns-over-variable expenses (see Figures 3, 4, and 5). As presented in graphic form, curves for all five farm sizes (80- to 1,280-acres), including each of the three farming systems, A, B, and C are concave from the top, or dish shaped. This pattern reflects the common practice on all farm units to substitute low water-consuming crops for those requiring more water, as water costs increase. Total farm net returns-less-variable expenses, as shown on the vertical axis, include net returns before deducting any allowance for fixed costs or for management returns. The horizontal fixed cost (FC) lines, parallel to the base for each farm size, intersect the respective net returns curves at points where the magnitude of these total farm net returns exactly equals all fixed costs. Perpendicular lines drawn from such intersections to the base line along which irrigation water variable expenses are indicated, identify the maximum prices that farmers can afford to pay per acre-foot for irrigation water at each of the farm sizes and still cover all fixed costs -- the break-even points. Total farm net returns at these break-even points, however, do not allow a return to the operator for supervision, management, and risk assumption. Farmers must obtain their irrigation water at lower cost than break-even levels in order to receive any returns for these services.

Figure 3

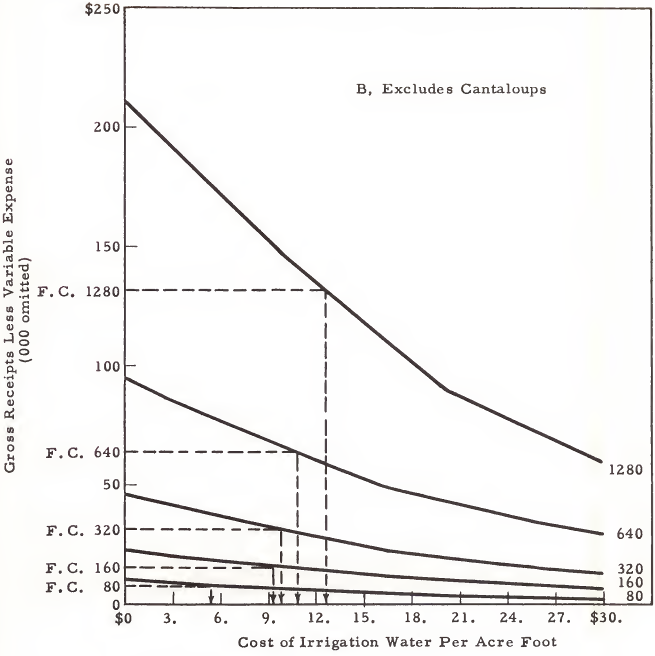
Farm Net Returns and Irrigation Water Variable Cost; Five Farm Sizes



Source: Table 4

Figure 4

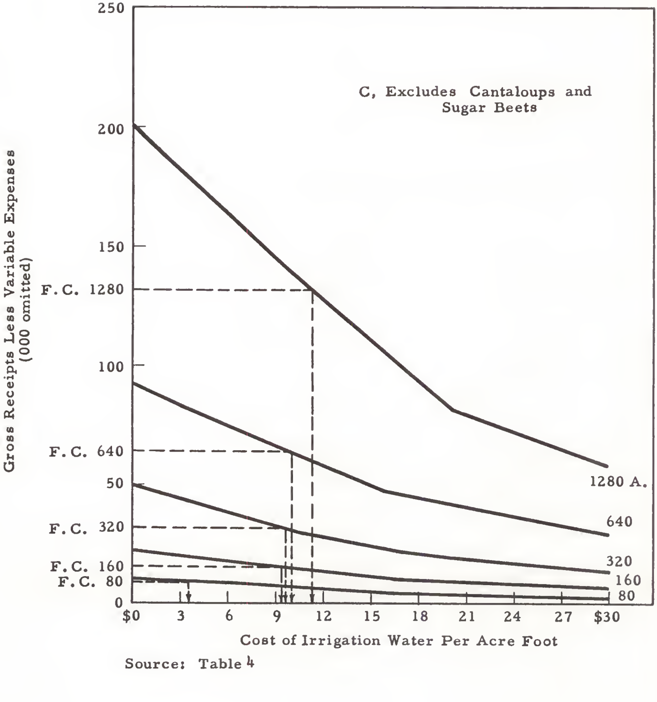
Farm Net Returns and Irrigation Water Variable Cost;
Five Farm Sizes



Source: Table 4

Figure 5

Farm Net Returns and Irrigation Water Variable Cost; Five Farm Sizes



Source: Table 4

Two conclusions are clearly evident from the data presented in Figures 3-5: First, a definite advantage accompanying increasing farm size; it enables farmers to pay higher prices for irrigation water and still cover fixed costs. Second, farmers able to produce and market effectively a wide range of alternative crops, including several specialty or high-net returns crops, also are able to cover higher water costs, and still break even, than those farmers operating systems allowing narrower ranges of crop choices (see Figures 3-5 and Table 4).

The importance of increasing farm size is clear; under all three cropping systems the magnitude of irrigation water costs accompanying the break-even point increase consistently with farm size. The widest differential occurs between the 80- and 160-acre models, but the effect of increasing scale in raising the break-even water price is clearly evident in comparing the other sizes. These data also emphasize the production cost problems that operators on small general crop farms face; this is evident in the fact that the break-even point for the 1,280-acre model comes at more than double the water prices per acre-foot associated with those for the 80-acre unit. Even the 160-acre model in this analysis enables farmers to equate total farm net returns with fixed costs at water prices almost double those that permit operators on 80-acre farms to break even.

The marked advantage to operators who are able to choose from among a list of alternative crops, including two or more that rank relatively high in net returns per acre, also is clearly evident in this analysis. Thus, the operator on a 1,280-acre farm using System A can pay $17 per acre-foot but the one limited to the alternatives under System C cannot pay more than $11.60 per acre-foot and still break even with total farm fixed costs (see Figures 3-5). Comparable data for the 80-acre model indicate that break-even water costs are $7.50 for System A, and $3.50 per acre-foot for System C. The differential advantage to operators with a choice among high return crops is distinctly greater when comparing Systems A and B than for similar comparisons between Systems B and C. This advantage in favor of the range of cropping alternatives identified as System A arises because it includes cantaloups as well as cotton, both of which crops rank decidedly higher than sugar beets in net returns per acre.

This analysis has demonstrated clear-cut advantages to those operators who, first, are able to operate farming units large enough to obtain cost reductions associated with farm size, and manage efficiently and, second, are in a position to plan cropping programs based on crops selected from a range of alternatives that includes several with relatively high net return per acre. Data already presented on variations in net returns per acre among crops included in this study clearly define the relationships among crops and show the advantages that farmers gain by producing one or more specialty crops in addition to cotton. It must be recognized when considering this question that farmers in general are not free to elect cropping System A or B in preference to System C. The markets for specialty crops are not sufficiently broad to accept all potential production at satisfactory prices. Actual production of such crops, therefore, is limited to those producers who are able to complete satisfactory marketing arrangements, as well as meet other special requirements such as adequate knowledge of production and harvesting technology and practices.

The initial importance of political and economic relationships in determining policies for expanding irrigation water supplies places the findings of this section in sharp focus. This is particularly true of those relating to how size affects ability to pay for irrigation water, quantities used at alternative prices, and, through its effect on quantities and prices, net earnings. First, it is essential to repeat and emphasize that the break-even points cited in the above analyses occur at levels of net returns-over-variable expenses adequate <u>only</u> to cover total farm <u>fixed costs</u>; they include no extra margin to reward operators for supervision, management, or risk assumption. These break-even points for total farm net returns versus fixed costs come at successively higher water variable expenses as the total size of farm operation increases; a fact that certainly is pertinent to public policy on water development. What specific meaning this relationship has, however, is not necessarily independent; it depends on policy decisions, on the social philosophy and system of value judgments held by the legislators and/or administrators who are responsible for establishing such public policies.

A single example will aid in bringing this problem into focus. Thus consider a situation in which advance determinations indicate that a price of $10.50 per acre-foot, representing variable expense components for irrigation water from the proposed project, will be adequate to recover project

costs appropriate to these variable expense charges. But, if the policy makers elect to establish this price, on the one hand, according to the relationships exhibited in Figures 3-5, they are pricing out of the market for this new water all growers on System C farms except those with the largest units, all on System B farms, except those with the two largest sizes, and the 80-acre operators on System A farms. In contrast, they are allowing some range of profit-opportunity above the break-even points for the more economically capable water buyers on the larger and more specialized farms. Some persons, therefore, would identify these net earnings advantages as "unearned increment." They might call for differential pricing or especially graduated taxes, to recover such gains. This is the type of decision area in which social and economic philosophy becomes critical in policy determination. The important shifts since World War II in size of farms and farm businesses, and the increasing relative importance of a relatively small fraction of all farms in dominating production of farm products for market, provide general proof of how important scale economies are in American agriculture. It is not surprising that this analysis, dealing with water as one critical variable input, obtains results consistent with the over-all trends.

VARIATIONS IN TOTAL ANNUAL QUANTITIES OF IRRIGATION WATER AVAILABLE GREATLY INFLUENCE CROPPING PROGRAMS, RESOURCE ALLOCATIONS, AND TOTAL FARM NET RETURNS

Net Returns Vary Directly with Water Quantities Available, Up to Optimum Use

The analysis in this section concerns itself with how variations in the total annual quantities of water available, at constant irrigation water variable expense per acre-foot, react on cropping programs, resource allocations, and net returns-over-variable expenses. Thus it holds price constant and examines the effects of varying supply, in contrast to the preceding section where the analysis focuses on price variations, allowing such price changes to regulate optimum quantities used. The same set of assumption, limitations, and constraints used in the prior section also applies to this analysis. Water variable costs are constant at $3 per acre-foot, total annual quantities available begin at zero, and increase continuously until each farm model can use no more water productively, or until canal and pumping capacities establish an upper limit, whichever comes first.

Variable resource linear programming, used for this section of the study, selects the optimum combinations of all possible cropping alternatives within the established framework of restrictions, according to a range of total annual quantities of water available at the specified $3 price per acre-foot. The analysis procedure at each water quantity for each farm size is to select the crop and acreage with maximum net returns per unit of total water required consistent with the specified restrictions. This process is repeated in sequence for different quantities until net returns per unit of water equal the unit cost ($3 per acre-foot in this analysis), or until the entire supply is used.

This analysis, as does the preceding one concerned primarily with price variations, considers two major questions: first, how size variations interact with varying quantities of irrigation water to affect total farm net returns-over-variable expenses; second, how differences in the range of alternative crops available to farm operators react on these same questions.

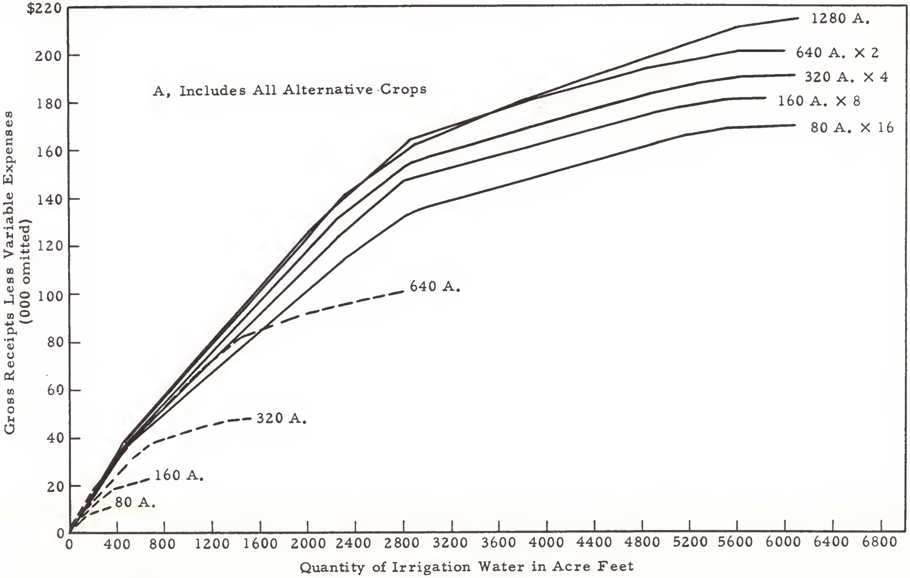
A problem immediately arises in comparing different farm sizes with respect to the amounts of water used and total farm net returns under optimum solutions. Size differences among these models mask important relationships. In order to overcome this difficulty, all farm sizes are compared in terms of 1,280-acre equivalents. We accomplished this comparison by multiplying each of the smaller sizes by an appropriate multiplier (i.e., 1,280 ÷ 80 = 16), and thus converting them to the 1,280-acre size equivalent (see Figures 6-8 and Table 5).

All farm sizes follow similar tendencies as the quantities of water available increase from zero to their maximum. Very steep increases (curve slopes) for early water additions indicate that the highest value crops per acre of water used come into the cropping program first. Decreasing rates of increase for total farm net returns-over-variable expenses accompany later water additions as lower-valued crops expand, and as operators apply additional water to the higher-valued enterprises. These curves become quite flat, particularly for the smaller farms and for farms with A and B alternative crops, at the highest water applications.

The comparisons among all five farm sizes, adjusted to a 1,280-acre equivalent, reveal sharp differentials among farm sizes in the relationship between water quantities used and net farm returns-over-variable expenses. Thus as 2,400 acre-feet of water used, a single 1,280-acre farm obtains $32,000 greater

Figure 6

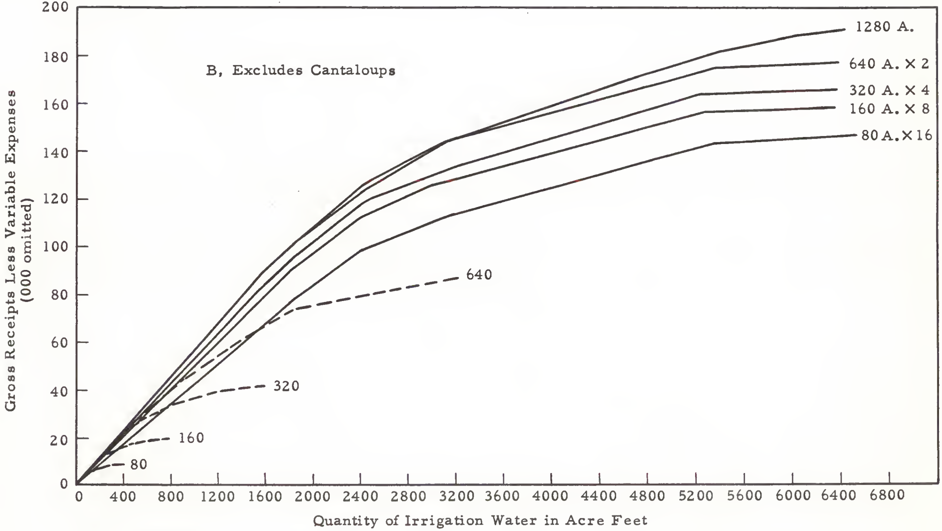
Farm Net Returns at Varying Quantities of Irrigation Water; Five Farm Sizes



Source: Table 4

Figure 7

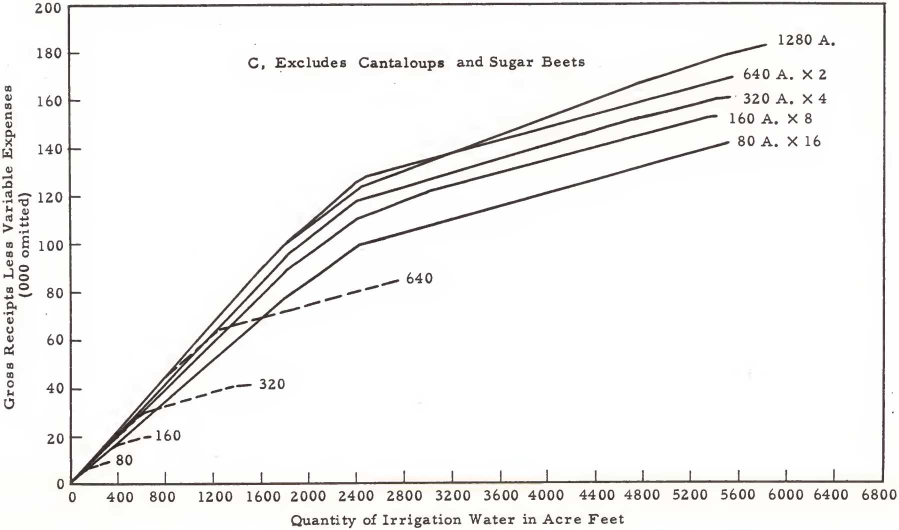
Farm Net Returns at Varying Quanties of Irrigation Water;
Five Farm Sizes



Source: Table 4

Figure 8

Farm Net Returns at Varying Quantities of Irrigation Water;
Five Farm Sizes



Source: Table 4

TABLE 5

Variations in Farm Net Returns Under Varying Quantities of Irrigation Water, Five Farm Sizes

80 acres								
A[a]			B			C		
Income	Irr. water	Net[b] returns per additional acre foot	Income	Irr. water	Net[b] returns per additional acre foot	Income	Irr. water	Net[b] returns per additional acre foot
dollars	acre feet	dollars	dollars	acre feet	dollars	dollars	acre feet	dollars
0	0	0	0	0	0	0	0	0
2,145	28	76.61	4,772	112	42.61	4,772	112	42.61
2,360	32	53.75	6,110	150	35.21	6,110	150	35.21
7,133	144	42.62	6,251	155	28.20	6,251	155	28.20
8,270	176	35.53	7,056	197	19.17	8,163	294	13.76
8,391	181	24.20	8,967	337	13.65	8,826	344	13.26
8,519	187	21.33	8,994	340	9.00	8,913	382	2.29
10,170	309	13.53	9,152	410	2.26			
10,302	320	12.00						
10,531	347	8.48						
10,539	348	8.00						
10,549	351	3.00						
10,613	380	2.24						

160 acres								
A			B			C		
Income	Irr. water	Net[b] returns per additional acre foot	Income	Irr. water	Net[b] returns per additional acre foot	Income	Irr. water	Net[b] returns per additional acre foot
dollars	acre feet	dollars	dollars	acre feet	dollars	dollars	acre feet	dollars
0	0	0	0	0	0	0	0	0
4,334	56	77.39	11,102	224	49.56	11,102	224	49.56
15,435	280	49.56	14,124	300	39.76	14,125	300	39.78
15,865	289	47.78	15,666	379	19.52	15,368	392	13.51
18,359	351	40.23	18,370	582	13.32	18,992	664	13.32
18,671	369	17.33	19,413	662	13.04			
21,866	609	13.31	19,488	672	1.50	19,022	668	7.50
22,142	636	10.22	19,541	702	1.77			
22,151	637	9.00				19,036	671	4.33
22,584	694	7.60						
22,652	728	2.00						

320 acres								
0	0	0	0	0	0	0	0	0
9,243	115	80.37	20,478	390	52.51	20,478	390	52.51
29,721	505	52.51	23,416	448	50.66	23,416	448	50.66
32,659	562	51.54	29,193	599	38.26	29,193	599	38.26
33,538	580	48.83	29,758	620	26.90	29,758	620	26.90
38,233	703	38.17	33,117	779	21.13	37,612	1,190	13.78
38,691	720	26.94	33,603	813	14.29	40,108	1,375	13.49
39,416	759	18.59	38,944	1,200	13.80	40,189	1,457	.99
42,331	963	14.29	40,773	1,338	13.25	40,196	1,507	.14
45,735	1,210	13.78	40,832	1,343	11.80			
46,978	1,330	10.36	40,997	1,360	9.71			
47,456	1,377	10.17	41,019	1,363	7.33			
47,667	1,400	9.17	41,181	1,529	.98			
47,784	1,465	1.80	41,239	1,598	.84			
47,836	1,519	.96						

640 acres								
0	0	0	0	0	0	0	0	0
19,060	229	83.23	43,995	780	56.40	43,995	780	56.40
63,056	1,009	56.41	49,861	895	51.01	49,861	895	51.01
68,922	1,125	50.57	62,581	1,198	41.98	62,581	1,198	41.98
70,681	1,160	50.26	63,842	1,240	30.02	63,842	1,240	30.02
81,096	1,408	41.99	72,038	1,563	25.37	68,867	1,616	13.36
82,128	1,443	29.49	73,093	1,626	16.75	83,953	2,746	13.35
83,546	1,517	19.16	73,130	1,628	18.50	84,006	2,750	13.25
90,448	1,926	16.87	83,082	2,374	13.34	84,151	2,761	13.18
90,787	1,950	14.12	87,134	2,689	12.86	84,152	2,762	1.00
97,550	2,457	13.34	87,464	2,727	8.68			
99,312	2,650	9.13	87,489	2,735	3.12			
100,641	2,807	8.46						

1,280 acres								
0	0	0	0	0	0	0	0	0
37,780	459	82.31	87,376	1,560	56.01	87,376	1,560	56.01
125,156	2,019	55.99	99,128	1,790	51.10	99,128	1,790	51.10
136,908	2,250	50.87	122,488	2,397	38.48	122,488	2,397	38.48
140,427	2,320	50.27	140,554	3,042	28.01	124,753	2,481	26.96
159,553	2,817	38.48	142,820	3,127	26.66	165,254	4,774	17.66
161,408	2,886	26.88	144,316	3,196	21.68	177,743	5,482	17.64
171,201	3,337	21.71	145,374	3,250	19.59	177,931	5,492	18.80
180,911	3,853	18.82	171,513	4,731	17.65	178,472	5,524	16.91
198,812	4,866	17.67	182,761	5,388	17.12	179,540	5,674	7.12
204,119	5,180	16.90	184,132	5,470	16.72	182,448	6,121	6.51
211,279	5,615	16.46	188,319	6,057	7.13			
214,470	6,017	7.94	191,102	6,463	6.85			
215,067	6,100	7.19						

a/ A. Includes all Alternative Crops.
B. Excludes Cantaloupes.
C. Excludes Cantaloupes and Sugar Beets.

b/ Change in farm net return + change in quantity of irrigation water used.

net returns than the total for sixteen 80-acre farms (see Figure 6 and Table 5). The comparable values at 4,800 acre-feet of water used indicate an advantage of $37,000 for a single 1,280-acre farm as contrasted with 16 of the smaller units. In general, the closest relationship (the least difference in net returns) is between the two larger farm sizes. This close resemblance holds for all three farming systems studied, although the difference does tend to widen for the later water applications, at higher total quantities. At the other extreme, the widest difference between total farm net returns for two sizes as water quantities increase, occurs in comparing the 80- and the 160-acre farm sizes. We pointed out above that the 1,280-acre farm has lower alfalfa harvesting costs per unit than the other sizes; this differential also is important for the higher water applications in explaining the difference between this model and the 640-acre unit.

All five farm sizes also show net returns advantages as the range of alternative crops widens, particularly in comparing System A with Systems B and C. Thus at 2,400 acre-feet of water total use the 1,280-acre System A model has an advantage of about $18,000 over Systems B and C in net returns. This advantage widens to about $27,000 excess for A, as compared with B, and about $33,000 advantage for A as compared with C at 4,800 acre-feet of water. Again it is evident, in water quantities as well as in price variations, that distinct advantages accrue to farmers whose range of alternative crops include two or more with relatively high net returns per acre (as represented primarily by System A, but to some degree by System B) among our analytical models.

Optimum Cropping Programs Shift with Variations in Quantities of Water Available

The analysis that determined the effects of varying total annual quantities of irrigation water available also reveals how such variations react on crop choices, cropping programs, and acreage allocations, according to the five farm sizes. Data for System B alternative crops indicate marked similarities among these five analytical models. The sequence in which crops enter the cropping program as water quantities increase is; cotton, blackeye beans, sugar beets, and alfalfa hay (see Figures 9-13). In the three larger sizes, cotton enters the programs under medium or dry treatments; operators then shift to the wet treatment when adequate quantities of water become available.

Figure 9

Crop Acreage and Quantity of Irrigation
Water Used; 80 Acre Farm

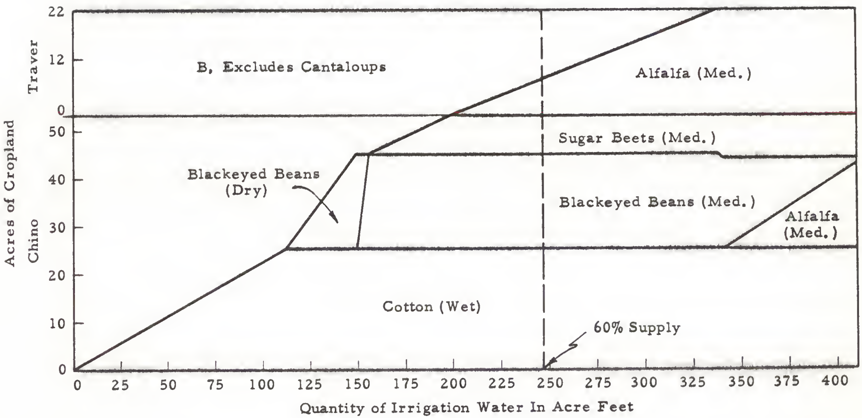


Figure 10

Crop Acreage and Quantity of Irrigation
Water Used; 160 Acre Farm

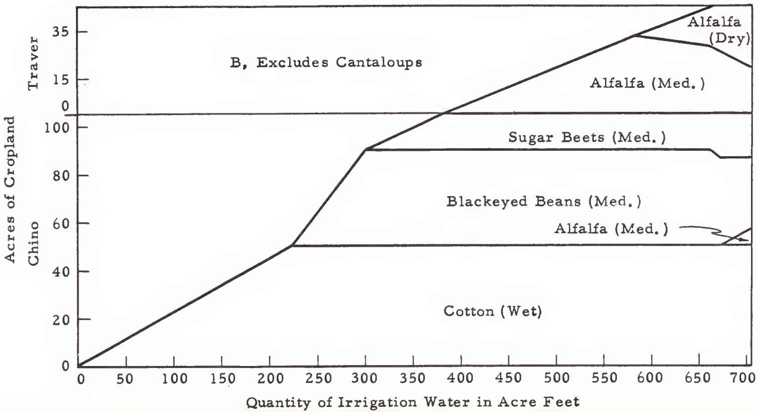


Figure 11

Crop Acreage and Quantity of Irrigation Water Used; 320 Acre Farm

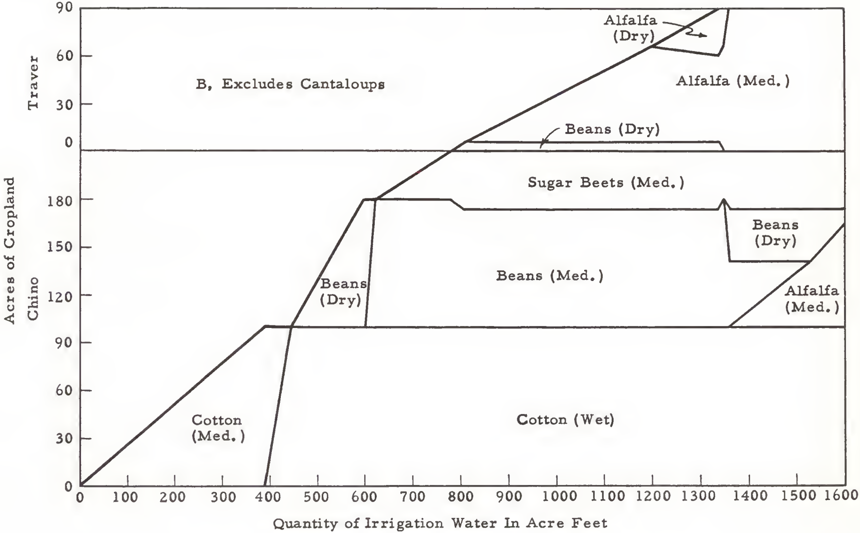


Figure 12

Crop Acreage and Quantity of Irrigation
Water Used; 640 Acre Farm

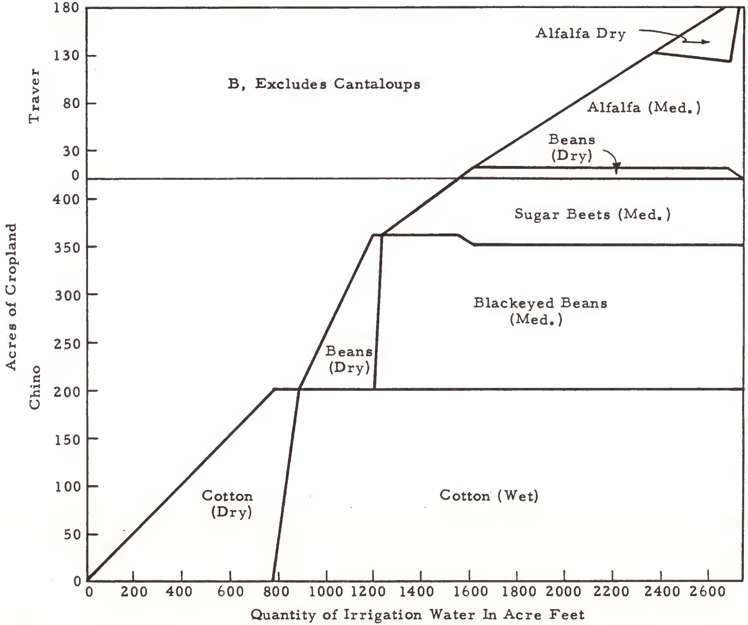
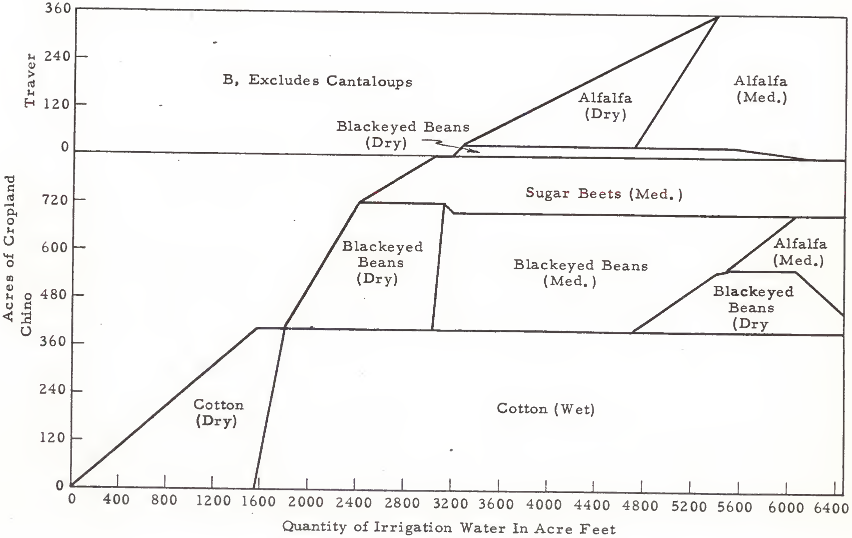


Figure 13

Crop Acreage and Quantity of Irrigation
Water Used; 1280 Acre Farm



Earlier increments in the sequence of expanding water quantities are concentrated on the top quality soils with the less productive land coming into use only at later increments as total water quantities near the maximum total. The final increments in this sequence go to expand alfalfa production, and to provide wetter irrigation treatments for some of the crops brought into the program at smaller total quantities of irrigation water.

Data for the 320-acre farm size illustrate the tendencies toward a common pattern in shifting the cropping program as more water becomes available. Cotton is the first crop to enter the program, at the maximum allowable acreage and using the medium irrigation treatment. This crop shifts to the wet treatment as soon as increasing water quantities permit. Blackeye beans come into the program next (dry, then medium treatments), and sugar beets follow, as water quantities continue to increase. Later, a portion of the blackeye beans shifts to lower quality soil and sugar beets replace them on the better soils to the maximum allowable acreages for both crops. Finally alfalfa enters the program on the 320-acre size and absorbs the remaining increases in water quantity, using these final increments to shift from dryer to wetter irrigation treatment (see Figure 11).

This analysis also indicates the most profitable cropping program under limited water supply conditions. Thus two different cropping programs for the B alternative crops on the 80-acre farm, with distinctly different distributions of crops by acreages, will maximize net farm returns at maximum water availability and at 60 percent of such quantities, respectively:

100 percent of maximum supply				60 percent of maximum supply			
Soil	Crop	Treatment	Acres	Soil	Crop	Treatment	Acres
Chino	Cotton	Wet	25.0	Chino	Cotton	Wet	25.0
	Alfalfa	Medium	17.0		Beans	Medium	20.0
	Beans	Medium	3.0		S. beets	Medium	8.0
	S. beets	Medium	9.0	Traver	Alfalfa	Medium	7.5
Traver	Alfalfa	Medium	22.0		Idle		15.5
Total Cropland			76.0	Total Cropland			76.0

The fact that alfalfa, a perennial crop, provides economic yields for two or three years after establishment necessarily modifies operator policies in adjusting to limited water conditions expected to last not more than one year.

An operator facing this situation should make his adjustment to the limited quantities of water available by shifting acres allocated to various annual crops. In contrast, if the farmer expects reduced water supplies to continue for several years, he should shift out of alfalfa.

Net Returns Per Additional Acre-Foot of Water Vary Inversely with Quantities Available

It is evident in the preceding section that initial water quantities yield the highest profits when allocated to cotton and other relatively higher net return crops. Only after all acres available for planting in these higher net returns crops have received the maximum amount of water that they can use profitably will operators find it to their advantage to allocate additional quantities of water to the lower return enterprises. Results of these water allocation policies show quite distinctly in the declining net returns per acre-foot for successively added increments of water supply. We calculated these net returns per acre-foot for the successively added amounts of water at each of the optimum solutions according to varying water quantities (see Table 5). The amounts of water added at the successive optimum solutions as quantities vary are not necessarily consistent among the several cropping systems within one farm size, or within the five farm sizes for a particular cropping system. In spite of this difficulty, several facts stand out clearly in the data. First, the additional net returns decline consistently for all three of the cropping systems within each farm size. Second, there is evidence that net returns per additional acre-foot at the initial optimum solutions are higher for the larger sized farms than for the smaller ones; these magnitudes are \$82 and \$83, respectively for the two largest sizes, and \$77 for each of the two smaller ones (see Table 5). Third, the evidence is clear-cut that net returns per additional acre-foot are higher for the System A group of alternative crops than for those in B or C; little difference is evident as between the latter two systems. Data are available to provide a more complete perspective on how consistently and to what extent net returns per additional acre-foot diminish with successively added water increments. Such information on net returns per added acre-foot of water over the entire range of increasing quantities for the 320-acre and the 1,280-acre System B models appear in the following text table.

B. 320 acres			B. 1,280 acres		
Water		Net returns per added acre-foot	Water		Net returns per added acre-foot
Total	Increments		Total	Increments	
390	390	52	1,560	1,560	56
448	58	51	1,790	230	51
599	151	38	2,397	607	38
620	21	27	3,042	645	28
779	159	21	3,127	85	27
813	34	14	3,196	69	22
1,200	387	14	3,250	54	20
1,338	138	13	4,731	1,481	18
1,343	5	12	5,388	657	17
1,360	17	10	5,470	82	17
1,363	3	7	6,057	587	7

The 320-acre model shows net returns averaging $52 per acre-foot for the first water increment and the first optimum solution. Declines are consistent as quantities increase from the 390 acre-feet at this initial point until the net returns per additional acre-foot for the final 3 acre-feet increment amounts to only $7. The pattern of declining net returns per additional acre-foot is quite comparable for the 1,280-acre size. Beginning with an average of $56 per acre-foot for the first 1,560 acre-feet, this model shows a return of $7 per acre-foot for the final 587 acre-foot unit.

WATER COSTS, QUANTITIES AVAILABLE, AND FARM SIZE AFFECT FARM PROFITS

Estimated total farm profits are useful in evaluating the results of this study, in order to make comparisons among farm sizes. Our calculations for determining such profits, as is true in evaluating profits and losses for most businesses, involve important assumptions and estimates. Total farm net returns-over-variable expenses, as provided by linear programming computations for each optimum solution, represent the starting point in calculating farm profits. Total farm fixed costs, subtracted from these net returns, yield net returns over both and fixed and variable costs ranging from -$1,364 for the 80-acre size to $46,955 for the 1,280-acre model (see Table 5). But allowances for the operator's actual field work and for interest on total farm investments at an estimated "going market rate" (6 percent in this study) were deducted in arriving at these residuals. It is necessary, therefore, to add these values back in order to arrive at net farm income, which ranges from approximately

TABLE 6

Farm Profits (Capital and Management Income); Five Farm Sizes, Irrigation Water $3.00 per Acre-Foot[a/]
(C. Excludes Cantaloups and Sugar Beets)

	80 acres	160 acres	320 acres	640 acres	1,280 acres
	dollars				
Farm capital[b/]	65,708	123,958	251,614	505,885	1,022,091
Farm net returns	8,913	19,036	40,196	84,152	182,448
Total Fixed Costs	8,477	15,618	31,979	64,000	131,893
Net returns over fixed costs	436	3,418	8,217	20,152	50,555
Add					
Value operator's work[c/]	1,800	3,000	2,400	1,800	0
Interest on capital	3,857	7,392	15,108	30,352	61,299
NET FARM INCOME	6,093	13,808	25,725	52,304	111,854
Subtract					
Operator's wage[d/]	3,600	3,600	3,600	3,600	3,600
PROFIT (return to capital and management)	2,493	10,208	22,125	48,704	108,254
Interest on capital at 6%	3,857	7,392	15,108	30,352	61,299
Management income[e/]	-1,364	2,816	7,017	18,352	46,955
RATE EARNED	3.8%	8.2%	8.8%	9.6%	10.5%

a/ See footnote 1 page 11 for definitions of terms used in this report.

b/ Average investment in farm property.

c/ Calculated at $1.20 per hour for time in field work, already included in variable expenses.

d/ Full-year wages for operator's time at hired worker rates.

e/ Reward for decision making and other management functions.

$6,100 for the 80- to $111,850 for the 1,280-acre farm (see Table 6). These amounts represent the returns from the farm operations to cover three important productive services; wages for the operator's time, regardless of how he distributes it as between actual farm work and supervisory activities; interest on farm investments in land and other property; and returns to the operator for supervision and management, and for assuming the risks inherent in using his capital in the farm operation.

By subtracting a standard deduction of $3,600, representing the allow ance for one year of the operator's time at going rates for farm labor ($1.20 per hour), it is possible to obtain for each farm size the dollar amounts representing profit, the combined return to capital and management. Only by imputing a return to capital, or to management, is it possible to allocate these profits for the five farm sizes between these two residual claimants, capital and management. Our procedure was to assume (impute) a standard rate for capital at 6 percent interest per year, as we imputed a return for the operator's wage (at a standard $3,600 per year). The amounts obtained by multiplying 6 percent times total average farm investments are subtracted from the residual profit value. Management income remaining varies from -$1,364 for the 80- to nearly $47,000 for the 1,280-acre farm model (see Table 6). These net amounts represent the returns to the operators, according to farm sizes, for assuming and performing management responsibilities, and for undertaking the risks to their capital involved in operating the respective farms.

Farm size sharply affects the absolute and relative magnitude of the amounts identified as management income in the above calculations. Some indications of how earnings tend to increase with farm size are available by comparing the proportionate gains as farm size doubles beginning with the 80- and 160-acre sizes and continuing through the 1,280-acre size. In every instance management income more than doubles while farm size exactly doubles from one model to the next. Another useful indication here is to compare relative rates earned on average farm investments for the several farm sizes. Such comparisons are obtained by expressing profit (ranging from $2,500 to $108,250 according to farm size) as percentages of annual average capital investments. These rates earned increase from 3.8 percent for the 80- to 10.5 percent for the 1,280-acre farm (see Table 6). Rates earned, as was true for other earlier analyses, clearly indicate the earnings advantages accompanying farm size increase under conditions of this study.

Several general observations are appropriate regarding the above earnings analysis. The data on average total farm investments clearly establish the magnitude of dollar capital required for modern commercial farming, and suggest some of the risk implications inevitable in an economy characterized by uncertainty. We selected 6 percent as the appropriate interest rate to use in imputing interest on capital and the residual management income on two assumptions: First, that competition should assure capital employed in agriculture earnings equivalent to those in other uses. Second, that 6 percent per annum represents a reasonable approximation of the going (or market) rate.

None of these earnings measure as calculated here, for any farm size, should be viewed as "average" or representative of actual operations on a particular individual farm in the study area. In the first place, all net returns-over-variable expenses resulting from procedures in this study reflect optimum crop combinations to maximize net returns under the particular combination of conditions applying to each solution. Second, all basic calculations used in determining net returns-over-variable expenses per acre for the various crop enterprises under the specified conditions assume perfect knowledge regarding expected prices and costs, input-output ratios and yields, and resource availability. We also recognize that the study procedures, particularly those used in assembling farm organization and operations characteristics, do not necessarily result in precisely accurate information. Thus our land valuations represent carefully considered estimates, not actual market quotations. Inherent difficulties, furthermore, make it virtually impossible to include all overhead items that must be included if total farm fixed costs are to be precisely accurate.

These earnings measures are valuable, however, in making such comparisons among farm sizes as those cited above. They also suggest something of the financial complexity of modern farms. Most emphatically, however, they are not to be regarded as precise accounting data reflecting detailed farm earnings performance. They are more properly viewed as useful indicators of the relative variations in farm earnings according to size under the conditions of this study and in the study area.

FARM PRODUCT PRICES AFFECT GROSS RECEIPTS, NET RETURNS, AND ABILITY TO PAY FOR IRRIGATION WATER

Earlier portions of this analysis established the dominant importance of cotton on all farm sizes and under all three cropping systems studied. Only specialty crops with high gross, and net returns, can compete with cotton in profitability. In general, cotton occupies this preferred position not only in the study area but in the entire general crop area extending approximately from Merced County to the southern extreme of irrigated farming in the San Joaquin Valley. Thus any force that adversely affects cotton production will react unfavorably upon farm gross receipts, net returns, farm organization, land and other resource values, and the amounts of production capital available to farm operators. Cotton, therefore, lends itself quite well to the purposes of this analysis in which we undertake to determine how price variations for a principal farm product react upon cropping programs, total farm net returns, and ability to pay for irrigation water. Our approach is to determine what should be the production response for cotton, assuming no governmental price support or acreage limitations as lint prices vary from zero to about 40 cents per pound. All other conditions, restraints, and assumptions applicable in earlier sections of this study still apply for this linear programming model. Only those relating to cotton lint prices and acreage controls are relaxed, and these quite arbitrarily for analytical purposes only.1/

This analysis is based upon the B group of alternative crops. Actual cropping programs for all farm sizes, with cotton lint prices at zero, will include only the other alternative crops available under this system. Cotton will enter the programs only when two necessary conditions are met: First, gross receipts for an acre of cotton must exceed variable expenses; Second, the dollar magnitude of these net returns must exceed those from the least profitable crop already included in the program. Cotton lint prices at which these conditions are first met vary according to farm size. For the five analysis models they are as follows: 80-, 160-, 320-, 640-, and 1,280-acre, respectively, 23.9¢, 20.3¢, 19.4¢, 18.0¢, and 19.8¢ per pound (see Figure 14 and Table 7). Once cotton lint prices have risen sufficiently

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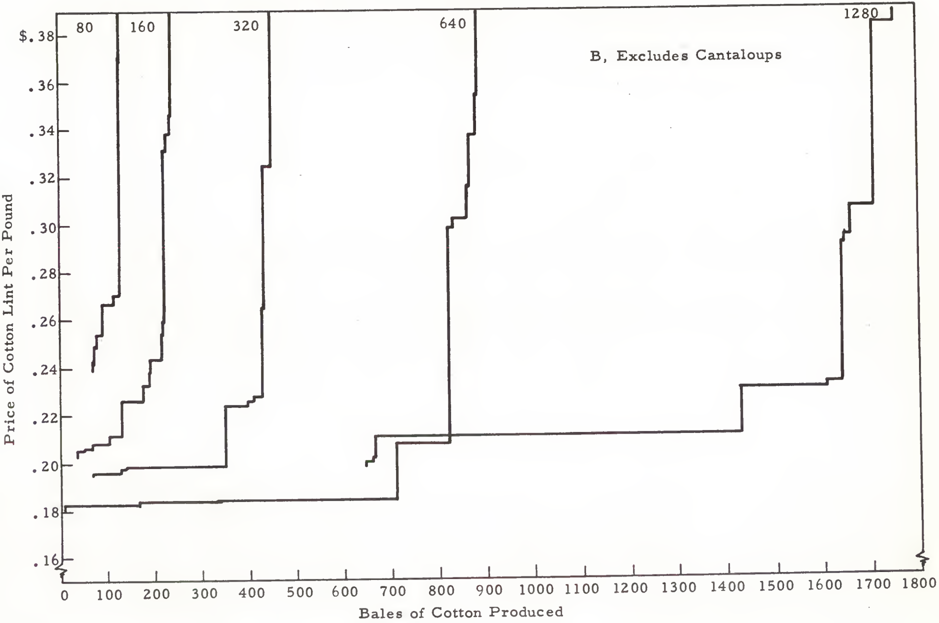
1/ The fact that prices and/or production of alternative crops also would be affected by these changes in cotton is recognized, but not considered, in this analysis.

Figure 14

Cotton Production at Varying Lint Prices
Five Farm Sizes



Source: Table 7

TABLE 7

Variations in Gross Receipts Less Variable Expenses and Cotton Production under Varying Cotton Lint Prices, Five Farm Sizes

B. Excludes cantaloups														
80 Acres			160 Acres			320 Acres			640 Acres			1,280 Acres		
Returns	Cotton lint	Lint price	Returns	Cotton lint	Lint price	Returns	Cotton lint	Lint price	Returns	Cotton lint	Lint price	Returns	Cotton lint	Lint price
dollars	bales	per lb.	dollars	bales	per lb.	dollars	bales	per lb.	dollars	bales	per lb.	dollars	bales	per lb.
7,913	0	0	12,452	0	0	25,933	0	0	51,973	0	0	132,438	0	0
7,913	71	.239	12,452	34	.203	25,933	70	.194	51,973	4	.180	132,438	645	.198
8,050	76	.243	12,490	50	.205	25,976	128	.195	52,047	332	.183	133,049	649	.200
8,290	79	.249	12,498	66	.206	26,087	143	.197	52,171	712	.184	133,700	662	.202
8,495	92	.254	12,500	67	.206	26,171	348	.198	60,616	807	.208	136,737	1,424	.211
9,075	114	.267	12,628	104	.209	30,619	398	.224	73,944	823	.240	150,619	1,611	.231
9,251	124	.270	12,696	132	.211	30,781	412	.225	97,783	829	.298	151,316	1,641	.232
12,001	125	.314	13,713	177	.226	31,262	429	.227	98,385	856	.300	200,479	1,646	.292
13,543	126	.339	14,427	190	.234	39,667	434	.266	99,470	864	.302	202,211	1,660	.294
15,581	128	.371	14,894	191	.239	52,133	447	.324	105,158	867	.315	212,736	1,712	.306
			15,395	216	.244	60,731	447	.362	114,551	881	.337	278,428	1,757	.383
			16,414	219	.254									
			17,208	224	.261									
			25,145	226	.332									
			25,870	235	.338									
			26,687	236	.345									

to meet the conditions necessary to bring cotton into the cropping programs, a very small additional price increase brings a sharp production response. The extent of these responses, according to the five farm sizes, is evident upon examining the percentage of total cropland planted to cotton according to varying cotton lint prices. At 20¢ per pound the 80- and 160-acre farms produce no cotton under the conditions of this analysis, while 320-, 640-, and 1,280-acre farms allocate 50.3, 51.6, and 23.9 percents, respectively, of total cropland to cotton (see Table 8). As cotton lint prices rise, the proportions of all cropland planted to cotton on the various farm sizes also increases; at 25¢ per pound they are as follows: 46.6, 63.3, 62.9, 60.6, and 59.0 percents, respectively, for the five farm models ranging from 80- to 1,280-acres in size. At 33¢ per pound for cotton lint (approximately the current support price level) about two-thirds of all cropland is allocated to cotton for all farm sizes except the 80-acre unit; here the proportion is approximately three-fourths of all cropland (see Table 8).

Very minor cotton acreage response results to lint price rises above the 33¢ level for any five farm size. Limited water quantities available during certain irrigation periods are important in explaining this result. If such deficiencies were corrected, the constraints in linear programming model used for this analysis are such that acreage might continue to expand in response to cotton price rises until cotton occupies all cropland, ignoring all other limiting factors.

The upper ceiling limit on cotton acreage expansion in response to lint price rises in this analysis is consistent with the over-all time element assumptions in this study. Inventories, capital investments, and fixed costs are for a short-run period, during which time is not available to accomplish changes in these important organizational characteristics. We could modify the assumptions here by allowing sufficient time to add new capital, drill additional wells, and increase quantities of water available at the critical periods in response to further cotton lint price gains. The result might be continued cotton acreage expansion in response to such price rises. But it is possible that other restraints would arise to limit such cotton acreage responses; biological and physiological conditions that can be corrected only with rotations difficulties in removing one year's crop in time to prepare the seedbed and plant the next one, conflicts and inefficiencies among the various resources and their availability in terms of proper timing; these and other factors might still limit acreage response to rising cotton lint prices.

TABLE 8

Percent Cropland in Cotton at Different Cotton Lint Prices, Five Farm Sizes

Farm size	Cropping alternative B		
	Cotton lint $.20/pound	Cotton lint $.25/pound	Cotton lint $.33/pound
	percent		
80 acres	0	46.6	76.0
160 acres	0	63.3	66.0
320 acres	50.3	62.9	67.2
640 acres	51.6	60.6	65.7
1,280 acres	23.9	59.0	64.5

Acreage Expansion Likely at Lower Lint Prices;
Total Farm Net Returns Also Could Drop

Total farm net returns increase rapidly once cotton lint prices rise sufficiently to bring cotton into the cotton programs (see Figure 15). The particular lint price associated with break-even net returns (point at which the break-even line intercepts the net returns curve) varies according to farm size and water costs. With irrigation water variable cost at $3 per acre-foot on the 80-acre model, the break-even cotton lint price is about 27¢ per pound. If these irrigation water costs rise to $9 per acre-foot, the break-even lint price is at 30¢ per pound. Larger farm sizes have a lower break-even price for lint at $3 per acre-foot for irrigation water, 25.5¢ per pound for the 160 size, 27.5¢ per pound for the 320-, and 21.6¢ per pound for both the 640- and the 1,280-acre farms. Once more the evidence is clear that as farm size increases farmers gain an advantage in higher total farm net returns-over-variable costs and in increased ability to pay for irrigation water.

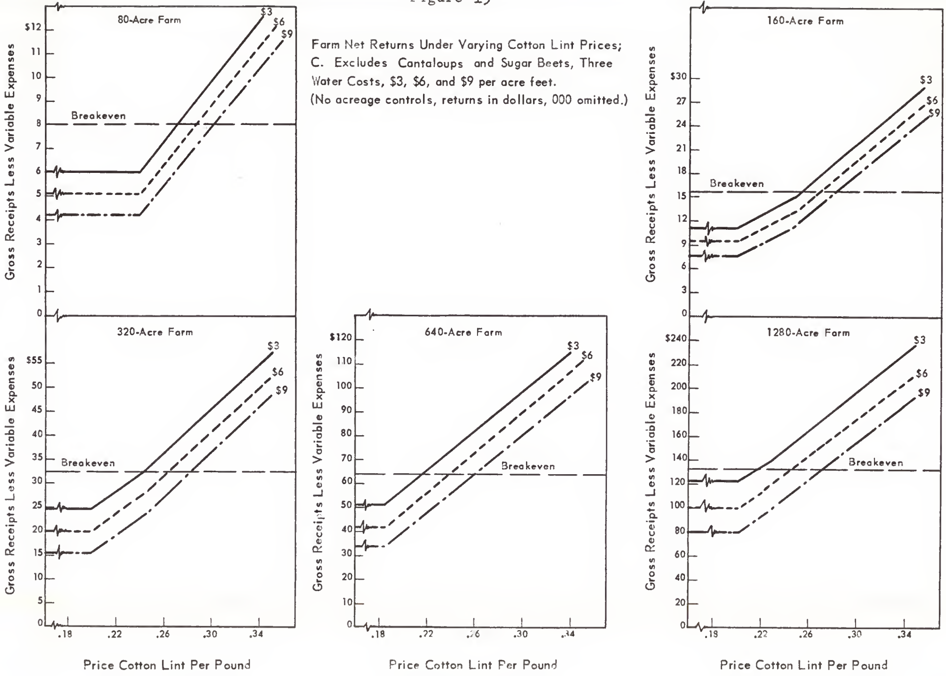
The above analysis supports several important conclusions. First, extremely sharp increases in cotton acreage and production in the San Joaquin Valley would result under conditions specified in this study following government action terminating price supports and acreage restrictions. This analysis indicates that marked expansion would occur, even if United States cotton lint prices dropped to the world level, about 24.5¢ per pound (as contrasted with existing support prices at approximately 33¢ per pound). Experience with plans A and B, in effect during the 1959 and 1960 seasons, supports this view; marked acreage expansion did occur with accompanying production gains in California and other western areas.

Second, sharply reduced cotton lint support prices will react much more unfavorably on earnings by operators on the smaller, than those on the larger San Joaquin Valley cotton-general crop farms. The higher break-even lint prices for smaller farms, as compared with the larger ones in this analysis, clearly support this conclusion (see Figure 15).

Third, farmers and those responsible for planning and developing sources of additional irrigation water should not expect gains in cotton net returns per acre (except possibly through yield increases) to underwrite any future increases in irrigation water costs. Expanded acreage and production within

Figure 15

Farm Net Returns Under Varying Cotton Lint Prices; C. Excludes Cantaloups and Sugar Beets, Three Water Costs, $3, $6, and $9 per acre feet. (No acreage controls, returns in dollars, 000 omitted.)



the framework of existing price supports, of course, would contribute to such increased purchasing ability. But current cotton lint export subsidy rates were about 8.5¢ per pound for the 1961 crop; it is not likely that they will increase markedly. This prospect, in conjunction with the evidence from this analysis that cotton production on the farm sizes where the bulk of the crop is produced in California, would greatly expand at sharply lower lint prices, leaves little room for optimism regarding further increases in net returns per acre from cotton due to price rises. Such improved purchasing power may come over the long run from increased cotton acres and from expanded opportunity for farmers to produce high gross value specialty crops in addition to cotton on San Joaquin Valley crop farms.

SIZE ADVANTAGES HERE SUGGEST ECONOMIES OF SCALE

Earlier sections of this report have indicated that definite increases in total farm net returns-over-variable expenses accrue quite consistently among the analytical models as size increases from the 80- to the 1,280-acre farm. These earnings advantages are most marked in comparing the two smaller sizes, with the 160-acre unit favored over the 80-acre farm. In general, continued gains in earning power accompany size increase (in acres) for all five farms. These earnings advantages appear relatively smaller for the two larger sizes, the 640- and 1,280-acre models, than for the 80- versus the 160-acre units. Such advantages, accruing to farms of like organization as a result of increasing size, merit special consideration. Is it possible to identify and evaluate the forces associated with these size-related advantages? The economic concepts included under economies of scale may be useful in this respect. These ideas have to do with the relationship of changes in scale of operation to average total cost per unit of product; they involve two time contexts, the short term and the long term. In the former the total physical "plant" and associated costs are unchanged (fixed) for the production period; in the latter, ample time is available for changing (expanding) the physical facilities, so that not even the costs associated with the plant are fixed; they become variable.1/

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1/ See Viner, Jacob, "Cost Curves and Supply Curves," Zeitschrift fur Nationalokonomic, Vol. 3 (1931), pp. 23-46. Reprinted in American Economics Association, Readings in Price Theory, London: George Allen and Unwin, Ltd., 1956.

Inputs and costs that vary directly with production volume, such as materials, labor, and certain other items are variable in both time contexts. Variations in average total cost per unit of product associated with changes in volume in either the short- or the long-term period are easiest to identify and measure if (a) the analysis concerns a firm producing a single product, and, (b) if it can be expressed in costs per unit of physical product.

It is evident that the data and methods in this study do not lend themselves ideally to analysis according to the concepts included in economics of scale. First, the five analytical models definitely are multiple-product firms. Second, revenue dollars, or some other common denominator rather than the physical outputs will have to represent production. Third, the scope and organization of this study are such that only the short-term context applies to each of the five models. A fourth consideration is that the analysis in the preceding sections all focuses on variable costs, only, with fixed costs excluded until after optimum solutions were available from the linear programming procedures. In spite of these limitations in the data and the methodology, we believe it useful to examine to what degree the concepts included in economics of scale do aid in interpreting the empirical results of the preceding sections. We undertake, in the following sections, therefore, to explore the degree to which the relationships revealed by analyses in this study relate to and are consistent with those under the concept of economics of scale.

Scale Advantages Reflect Both Technical and Pecuniary Economies

Scale economies arise from decreases in unit production costs. In the form of reduced cost per unit of product, scale economies may result either from obtaining a greater volume of output for a given quantity of inputs (more favorable input-output ratios) or from purchasing production goods and services for lower prices, or from a combination of both. Technical economies, if they exist, usually will accompany more complete utilization of machinery and equipment. Such internal economies are not limited to getting more hours use per year and a greater volume of physical products, from a particular machine. They may accompany the shift to different, larger, or more efficient equipment made possible by expanded farm size. Dollar economies in purchasing usually reflect the success that larger operators

have in capitalizing upon listed quantity discounts or in obtaining special concessions. The fact that increasing proportions of the total inputs used in modern farming represent dollar purchases from off-farm commercial sources underscores the importance of these pecuniary purchasing economies.

Theoretical Basis for Scale Economies.--Economists long have recognized that scale economies exist, and that they frequently are an important consideration in planning production operations. A production possibility chart showing alternative combinations of resources that may be used to produce different quantities of a particular product is useful for examining some of the basic ideas related to scale economies (see Figure 16). Four hypothetical equal-output (iso-product) curves indicate the manner that resources can substitute for each other in producing four distinct quantities of product, in this instance 100, 200, 300, or 400 bales of cotton. The straight lines represent equal cost (iso-cost) combinations of two production inputs, labor and land, at each level of production. The least-cost combination of labor and land for producing the indicated number of bales of cotton at each of the output levels is at the point where one of the curves Q1, Q2, Q3, or Q4 just touches (is tangent to) the equal cost line (see Figure 16). The result of connecting these minimum cost points (as in Figure 16 when the "Expansion Path" line is superimposed) is to establish the optimum path for increasing production. Along this expansion path the proportions of labor and land change as production volume increases; through these changes an operator may produce at minimum costs. In contrast the "True-Scale" line maintains a constant proportion of labor and land at all levels with the result that costs per unit of product are higher than those at which it is possible to obtain the four product quantities along the expansion path.1/ These hypothetical curves underscore a major problem in planning production organization to minimize cost of production per unit. The operator who hopes to accomplish this goal must understand his cost structure and effectively vary the proportions of his resources according to the volume of production in order to take full advantage of scale economies.

Short-Run Versus Long-Run Average Cost Curves.--This study applies the traditional short- and long-run average total-cost-per-unit curve concepts in analyzing economies of scale (see Figure 17). For the short run, land, water supply, and machinery are considered in fixed supply; the time period is

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1/ See also Heady, Earl O., Resource Productivity Returns to Scale and Farm Size, Iowa State College Press: 1956, p. 87.

Figure 16

Hypothetical Longrun Production Possibility Chart Showing Alternative Combinations of Resources as Cotton Output Increases

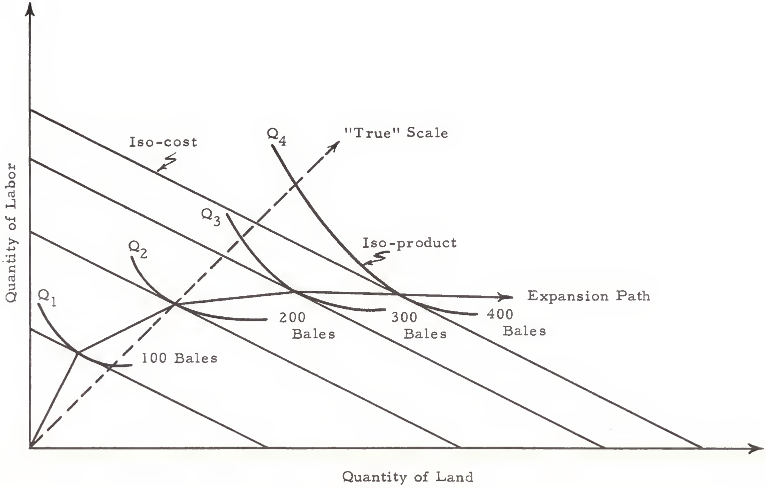
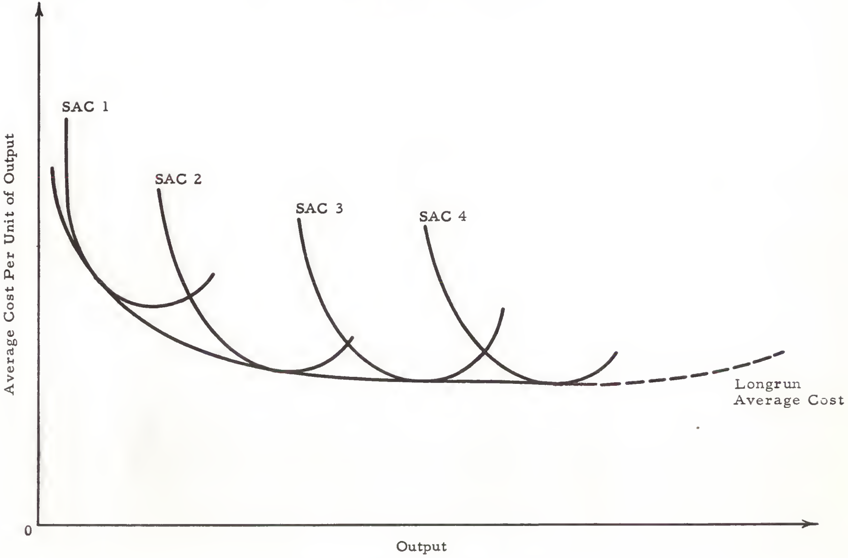


Figure 17

Hypothetical Shortrun and Longrun
Average Cost Curves



too short to permit changes. Other production inputs, primarily labor and production capital, are assumed to be available at the current market price in unlimited quantities. The distinction between short run and long run in this analytical framework is that the latter allows sufficient time for machinery to wear out and for operators to provide new irrigation facilities, and to purchase, improve, and add additional acreage to existing farms. Theoretical short-run average total-cost-per-unit curves traditionally display a typical U-shape, reflecting the manner in which a constant magnitude of total fixed cost is spread over an increasing number of units as production increases. These short-run cost curves follow the downward leg of the U until maximum utilization and efficiency is accomplished; further increases in production beyond this minimum cost-per-unit level causes the short-run cost curve to turn upward. This latter upturn reflects full utilization of fixed factors making it necessary to introduce other less efficient or more expensive inputs as a necessary condition for accomplishing the increased output.

A series of short-run cost curves can represent short-run average total-cost-per-unit under a succession of resource use conditions (see SAC 1, 2, 3, and 4 in Figure 17). The long-run average cost curve then is the "envelope" curve just touching (tangent to) each of the short-run curves in this series. Such a combination of short- and long-run cost curves represents the typical treatment of this topic familiar in economics textbooks. For planning purposes the long-run curve has parallel significance to the economies-of-scale expansion path in the production possibility chart (see Figure 16). Quite commonly, however, hypothetical diagrams show long-run average cost curves turning upward at the extreme right as suggested by the dotted line in Figure 15. This analysis did not establish any such tendency. Perhaps the reason may lie in the fact that the maximum farm size studied is a 1,280-acre unit. Upturns at the end of the long-run cost curve might reflect increasing costs accompanying extreme size, and the wide geographic areas involved in very large farms. This study excludes farms larger than 1,280 acres due to the relatively slight numerical importance of such large units in the study area.

Total Revenue as "Product" for Multiple Product Farms.--The previous discussion and the hypothetical charts relate to a farm or other firm producing a single product. The problem of identifying and measuring scale economies becomes highly complicated and much more difficult when a farm produces not a single

but a variety of products. Dean and Carter provide a detailed explanation of methods that may be used to measure output for a farm producing multiple products in a Yolo County Study.[1/] A satisfactory method for calculating average total cost curves when only a single product is involved consists simple of dividing total cost by the number of units of output at each production level. But this simple procedure is inadequate for farms including several products. We, therefore, use total revenue as the measure of output in calculating costs. This enables us to compare average total cost per unit of revenue (total cost divided by total revenue) as production expands for each of the three farming systems within each farm size. The low point on the cost curve reflects the optimum combination of products in relation to available resources to minimize cost per dollar of output, at constant prices.

Cost curves drawn according to data obtained in this way have essentially the same meaning as the traditional textbook cost curves (Figure 17). Linear programming solutions provided the total revenue and total cost magnitudes for a range of outputs maximizing net farm income within the framework of this study (see Table 9). We calculated short-run cost curves for each of the five farm sizes within each of the three sets of alternative crops, Systems A, B, and C, and plotted the resulting data to obtain cost curves similar to those in Figures 17 (see Figures 18-20). The short-run cost curves stop at the minimum with full use of the fixed factors (land and water).

Empirical Evidence From This Analysis Indicates Definite Size Advantages

Total revenue and total cost data, when expressed as ratios of total costs to total revenue, suggest the existence and importance of scale economies under conditions of this study.. The short-run cost curves for the five farm sizes fit within a common long-run cost envelope typical of a planning curve for the long run. Unit costs consistently decline over this long-run cost curve for each of the three groups of alternative crops. Sharpest cost reductions occur between the 80- and 160-acre farm size, with the cost savings tending to diminish as between pairs of farm sizes for successive increases (see Figures 18-20). The long-run planning curve for each system, however, shows continuing

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1/ Dean, Gerald W., and Harold O. Carter, Cost-Size Relationships for Cash Crop Farms in Yolo County, California, California Agr. Expt. Sta., Giannini Foundation Mimeo Rept. No. 238, Davis: December 1960.

Figure 18

Shortrun Average Cost Curves and Longrun Planning Curve

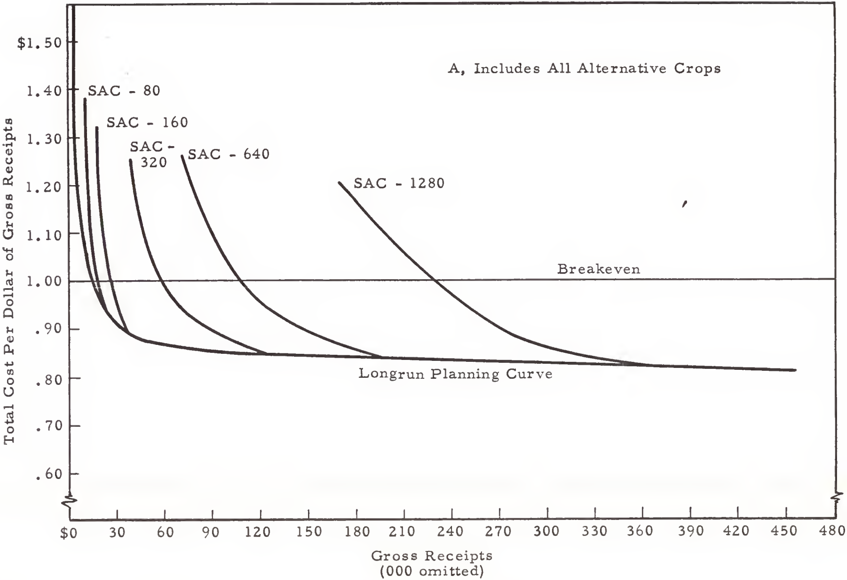

Figure 19

Shortrun Average Cost Curves and Longrun Planning Curve

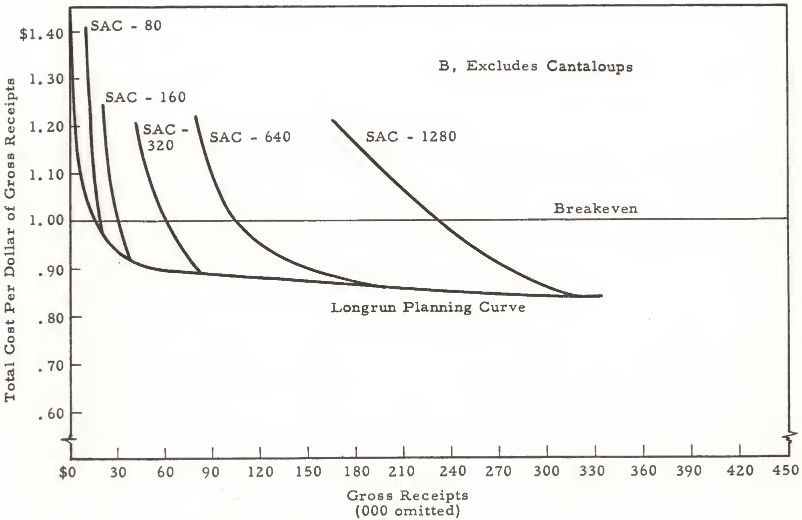

Figure 20

Shortrun Average Cost Curves and Longrun Planning Curve

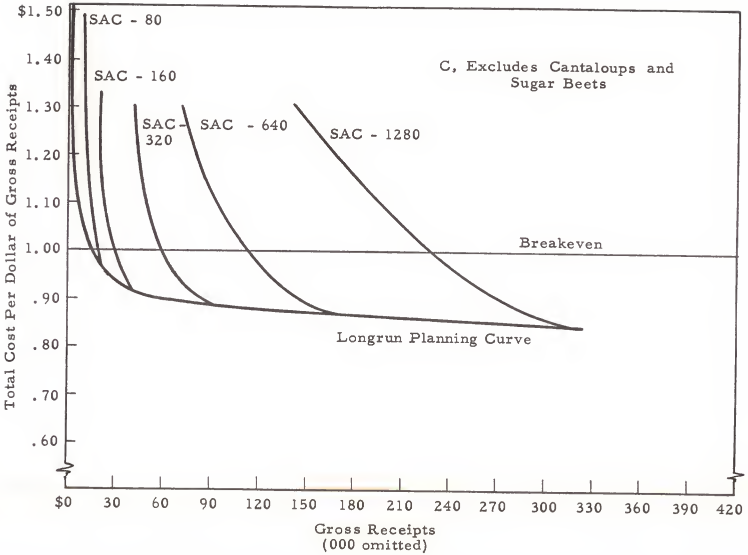

TABLE 9

Average Total Costs for Producing Varying Outputs, Five Farm Sizes

A. Includes all Alternative Crops						B. Excludes Cantaloupes						C. Excludes Cantaloupes and Sugar Beets					
Gross receipts 1(2+3)	Farm net returns 2	Variable expenses 3	Fixed costs 4	Total cost 5(3+4)	Ave. total cost 6(5/1)	Gross receipts 1(2+3)	Farm net returns 2	Variable expenses 3	Fixed cost 4	Total cost 5(3+4)	Ave. total cost 6(5/1)	Gross receipts 1(2+3)	Farm net returns 2	Variable expenses 3	Fixed cost 4	Total cost 5(3+4)	Ave. total cost 6(5/1)
dollars																	
80 acres																	
0	0	0	8,477	8,477	00	0	0	0	8,477	8,477	00	0	0	0	8,477	8,477	00
4,018	1,911	2,107	8,477	10,584	2.63	4,018	1,911	2,107	8,477	10,584	2.63	4,018	1,911	2,107	8,477	10,584	2.63
11,913	5,627	6,286	8,477	14,763	1.24	11,913	5,627	6,286	8,477	14,763	1.24	11,913	5,627	6,286	8,477	14,763	1.24
13,241	6,250	6,991	8,477	15,468	1.17	13,241	6,250	6,991	8,477	15,468	1.17	13,241	6,250	6,991	8,477	15,468	1.17
19,023	8,913	10,110	8,477	18,587	.98	17,294	8,149	9,145	8,477	17,622	1.02	17,294	8,149	9,145	8,477	17,622	1.02
24,733	10,365	14,368	8,477	22,845	.92	17,735	8,350	9,385	8,477	17,862	1.01	17,735	8,350	9,385	8,477	17,862	1.01
25,103	10,454	14,649	8,477	23,126	.92	19,023	8,913	10,110	8,477	18,587	.98	19,023	8,913	10,110	8,477	18,587	.98
26,129	10,613	15,516	8,477	23,993	.92	20,127	9,152	10,975	8,477	19,452	.97						
160 acres																	
0	0	0	15,618	15,618	00	0	0	0	15,618	15,618	00	0	0	0	15,618	15,618	00
20,997	11,102	9,895	15,618	25,513	1.215	20,997	11,102	9,895	15,618	25,513	1.215	20,997	11,102	9,895	15,618	25,513	1.215
27,957	14,125	13,832	15,618	29,450	1.053	27,957	14,125	13,832	15,618	29,450	1.053	27,957	14,125	13,832	15,618	29,450	1.053
30,876	15,368	15,508	15,618	31,126	1.008	30,876	15,368	15,508	15,618	31,126	1.008	30,876	15,368	15,508	15,618	31,126	1.008
39,540	18,992	20,548	15,618	36,166	.914	39,540	18,992	20,548	15,618	36,166	.914	39,540	18,992	20,548	15,618	36,166	.914
39,567	19,001	20,566	15,618	36,184	.914	39,567	19,001	20,566	15,618	36,184	.914	39,550	18,995	20,555	15,618	36,173	.914
40,176	19,180	20,996	15,618	36,614	.911	40,176	19,180	20,996	15,618	36,614	.911	39,558	18,997	20,561	15,618	36,179	.914
41,260	19,485	21,775	15,618	37,393	.906	40,377	19,222	21,155	15,618	37,173	.910	39,715	19,036	20,679	15,618	36,297	.913
41,298	19,497	21,807	15,618	37,425	.906	42,067	19,541	22,526	15,618	38,144	.906						
52,090	22,233	29,857	15,618	45,475	.873												
52,988	22,418	30,570	15,618	46,188	.871												
54,312	22,652	31,660	15,618	47,278	.870												
320 acres																	
0	0	0	31,979	31,979	00	0	0	0	31,979	31,979	00	0	0	0	31,979	31,979	00
41,984	23,416	18,568	31,979	50,547	1.203	41,984	23,416	18,568	31,979	50,547	1.203	41,984	23,416	18,568	31,979	50,547	1.203
55,904	29,758	26,146	31,979	58,125	1.039	55,904	29,758	26,146	31,979	58,125	1.039	55,904	29,758	26,146	31,979	58,125	1.039
74,058	37,613	36,445	31,979	68,424	.923	74,058	37,613	36,445	31,979	68,424	.923	74,058	37,613	36,445	31,979	68,424	.923
79,895	40,108	39,787	31,979	71,766	.898	79,895	40,108	39,787	31,979	71,766	.898	79,895	40,108	39,787	31,979	71,766	.898
96,207	44,361	51,846	31,979	83,825	.871	80,257	40,202	40,055	31,979	72,034	.897	80,320	40,189	40,131	31,979	72,110	.897
104,279	46,546	57,733	31,979	89,712	.860	83,129	40,896	42,233	31,979	74,212	.892	80,537	40,196	40,341	31,979	72,320	.897
107,955	47,456	60,499	31,979	92,478	.856	83,897	41,075	42,822	31,979	74,801	.891						
109,355	47,784	61,571	31,979	93,550	.855	85,033	41,292	43,741	31,979	75,720	.890						
109,630	47,836	61,794	31,979	93,773	.855												
640 acres																	
0	0	0	64,000	64,000	00	0	0	0	64,000	64,000	00	0	0	0	64,000	64,000	00
83,986	49,862	34,124	64,000	98,124	1.17	83,986	49,862	34,124	64,000	98,124	1.17	83,986	49,862	34,124	64,000	98,124	1.17
112,863	63,842	49,021	64,000	113,021	1.00	112,864	63,842	49,021	64,000	113,021	1.00	112,864	63,842	49,021	64,000	113,021	1.00
148,929	79,144	69,785	64,000	133,785	.90	148,930	79,144	69,785	64,000	133,785	.90	148,930	79,144	69,785	64,000	133,785	.90
160,118	83,881	76,237	64,000	140,237	.88	160,119	83,881	76,237	64,000	140,237	.88	160,119	83,881	76,237	64,000	140,237	.88
160,290	83,953	76,337	64,000	140,337	.87	160,291	83,953	76,337	64,000	140,337	.87	160,291	83,953	76,337	64,000	140,337	.87
160,765	84,151	76,614	64,000	140,614	.87	160,770	84,156	76,614	64,000	140,614	.87	160,770	84,156	76,614	64,000	140,614	.87
167,934	87,000	80,934	64,000	144,934	.86	168,001	87,067	80,934	64,000	144,934	.86						
169,382	87,459	81,923	64,000	145,923	.86	169,460	87,537	81,923	64,000	145,923	.86						
201,803	96,113	105,690	64,000	169,690	.84	169,606	87,490	82,116	64,000	146,116	.86						
219,220	100,639	118,581	64,000	182,581	.83												
1,280 acres																	
0	0	0	131,893	131,893	00	0	0	0	131,893	131,893	00	0	0	0	131,893	131,893	00
167,972	99,128	68,844	131,893	200,737	1.20	167,972	99,128	68,844	131,893	200,737	1.20	167,972	99,128	68,844	131,893	200,737	1.20
253,980	147,129	106,851	131,893	238,744	.94	253,980	147,129	106,851	131,893	238,744	.94	253,980	147,129	106,851	131,893	238,744	.94
302,827	174,186	128,641	131,893	260,534	.86	302,827	174,186	128,641	131,893	260,534	.86	302,827	174,186	128,641	131,893	260,534	.86
323,303	183,767	139,536	131,893	271,429	.84	323,303	183,767	139,536	131,893	271,429	.84	303,660	174,535	129,125	131,893	261,018	.86
335,741	189,081	146,660	131,893	278,553	.83	335,741	189,081	146,660	131,893	278,553	.83	321,108	181,722	139,386	131,893	271,279	.84
341,425	191,378	150,047	131,893	281,940	.83	341,425	191,378	150,047	131,893	281,940	.83	322,966	182,448	140,518	131,893	272,411	.84
367,965	198,643	169,322	131,893	301,215	.82												
424,113	211,602	212,511	121,893	344,404	.81												
439,453	215,067	224,386	121,893	356,279	.81												

cost reductions for its entire length, although most of the cost economics are attained as size increases from the 80- to the 640-acre size.

Farm profits also increase with farm size, as indicated on a per-unit-of-product basis by the increasing vertical distance between the break-even line and long-run planning curve. Here again, however, the gains from further size increases lessen after the 640-acre size so far as cost-per-unit savings are concerned. Larger farms have a double advantage: First, they show wider profit margins per unit; Second, these margins are multiplied times a greater volume in arriving at total farm profits. On the other side of the coin, however, the larger farms involve much greater investments, with consequent increases in the uncertainty and risk accompanying these larger capital requirements. In this analysis, as in previous comparisons, System A with the widest range of alternative crops holds much greater advantage over System B than the latter does over System C (limited essentially to blackeye beans and feed crops in addition to cotton). The widest difference in the shape of the cost curves is evident in comparing the curves in Figure 18 with those in Figures 19 and 20. The data for System A according to the five farm sizes, reflect the earnings advantages of high value specialty crops such as cantaloups. The result is to spread total costs over a much larger volume of gross receipts, and lower the minimum points for the short-run cost curves below those for alternative Systems B and C (see Figure 16). The groups of alternative crops available under these latter two systems do not include any capable of matching cotton and cantaloups combined in gross receipts. This revenue advantage somewhat improves the relative position of the smaller farm sizes under System A, as compared with the more typical combination of alternative crops represented by B and C.

In addition to lowering average cost per unit, a high value crop also tends to increase total farm profit through larger gross receipts. Comparative data on net returns-over-variable expenses per acre for alternative crops clearly establish cotton as the dominant high-gross-value-per-acre crop among the general crops adapted to the study area. Farm operators who are able to combine with cotton production one or more specialty crops that also produce relatively high gross value and net returns-over-variable expenses per acre (such as System A group of alternative crops) have a decided advantage over those operators who are not in position to produce the specialty crops. The added total farm gross receipts for an individual farm are distributed over the same total farm fixed costs and therefore favor a wider spread

between the break-even line and the average short-term total cost per unit (see Figure 18). In addition, the higher level for total farm gross receipts causes the minimum cost point to be farther to the right, to be associated with a greater dollar magnitude for gross receipts.

Farmers and others concerned with agriculture reasonably may ask two questions regarding the analysis in this section: First, how dependable are the results as indicators of future developments in costs and earnings opportunities on farms in the study area; Second, how may farmers use the implications of these results to improve their long-term planning? Two considerations are relevant in considering these questions: First, this analysis does not conflict with the basic theoretical framework governing production organization and scale economies; Second, results from analyzing the available empirical data are both internally consistent, and in agreement with the general pattern of farm costs and earnings in relation to farm size indicated for the study area.

A recent report by Dean and McCorkle of the California Agricultural Experiment Station includes data that are highly relevant in answering the second question above. Their analysis, supplying projections up to the year 1975 for California's agriculture, indicates relatively sharp increases in acreage and production of three major California farm crops or groups of crops that are important to the study area. Depending upon whether California maintains its existing share of total United States production or shifts to a somewhat different estimated share, this report suggests that fruits, vegetables, and cotton may show acreage increases ranging from 10 to 68 percent as compared with 1954-1957.[1/] These crops, except for cotton which we already know to be a high gross value crop, typically are specialty crops in the high-gross-value category. If these projections are realized and if these analytical results fairly measure farm cost and earnings opportunities, four general observations are appropriate. First, the flatness of the long-run planning curve indicates that there will be little tendency for farms to concentrate around any one optimum size (see Figures 18-20). Second, the existing tendency toward consolidating smaller size farms, particularly those of 160 acres or less, probably will continue.

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1/ Dean, G. W. and C. O. McCorkle, Jr., Projections Relating to California Agriculture in 1975, California Agr. Expt. Sta. Bul. 778, Davis: 1961.

Third, the long-run planning curve for System A, based on specialty as well as general crops, appears more appropriate than the curves for either the B or C systems. The Dean and McCorkle projections support this view, and, assuming that fruit and vegetable production continues to shift from the Santa Clara Valley and Southern California into the San Joaquin Valley, this tendency will be further intensified. Fourth, higher net returns to farmers in the study area should tend to increase their ability to pay for irrigation water. This latter improvement may, for example, support a higher irrigation water price level including both variable and fixed costs. Such a development would be consistent with the findings of this study that increasing farm size and adding high gross values specialty crops to farming systems tend to increase total farm net returns-over-variable expenses and profits.

To the extent that such increases in net returns-over-variable costs exceed total farm fixed costs by wider margins than those necessary to provide satisfactory returns for management, as such, they should tend to increase the amounts that farmers can use to pay for irrigation water. Whether they will be willing to use them for this purpose, either to purchase more water at the same prices, or to pay higher prices for the same quantities, will depend on the same demand-regulating forces already examined in a previous section.

CONCLUSIONS

Findings in this present study, based on five farm sizes one of which is the 640-acre unit in the earlier report, fully confirm and extend the conclusions in the first report. They identify the impact of farm size on how variations in water quantities and in water costs affect farm organization and earnings, and, since the five sizes collectively include most cotton-producing farms in Tulare County, they provide a reasonably complete perspective on all such farms in the study area. Our analyses indicate clearly that farm size does affect farmer ability to pay for irrigation water; the 1,280-acre model shows break-even net return-over-variable costs at about $12.60 per acre-foot, compared with $3.50 for the 80-acre unit, both costs based on a range of alternative crops that includes cotton, but no other high gross and net return crop. Farms of all sizes also show advantages to operators who are able to produce and market one or more of the specialty crops with relatively high net returns per acre, in addition to cotton.

We believe that our results deserve careful examination by both farmers, and those involved in making irrigation water available to them. Legislators, policy makers, and administrators concerned with developing and distributing water supplies occupy prominent positions in the latter category. Specifically, this study shows that farmers can improve efficiency, reduce average total costs per unit of product, and increase profits by applying the gains that come from scale economies. They should avoid operating farms of such small size that relatively high per-unit costs and low profits are inevitable. Farmers on cotton-general crop farms who do expand farm size, however, should expect to obtain most cost savings by the time they reach the 640-acre size. Further gains in profits accrue to operators on larger farms, of course, due to their greater volume of production, providing that such farmers are successful in obtaining cost savings due to scale economies. Managements earnings are negative on 80- and only $2,800 per year on 160-acre farms under conditions of this study.

Existing trends in farm size indicate that many, if not most, farmers recognize these size relationships with costs and earnings, and that they are striving to apply them to their own advantage by consolidating and increasing size of smaller operating units. We expect this trend to continue, but do not anticipate any strong tendencies toward concentration within a particular size interval.

The important conclusions from this size variation study for water-developers and distributors are five. First, there are practical limits at relatively low levels per acre-foot for water prices (costs) that will permit farmers to stay in business, much less to receive acceptable returns for management, supervision, and risking their capital. Second, farmer demand for irrigation water is relatively sensitive to water price changes, particularly within the higher ranges, and growers, therefore, can be expected to reduce quantities of water purchased and used as prices increase. Third, wide variations exist among farm sizes and cropping systems in the ability that farmers have to pay for irrigation water. Fourth, on most cotton-producing farms, this crop has superior ability at current price support levels to pay for water, as compared with other available alternatives, but is limited to its present contribution by acreage regulations. The authors believe, fifth, that increased production of cotton and specialty crops, and the time necessary for market growth permitting such expansion, offer the most likely possibility for strengthening farmer ability to pay for irrigation water in the San Joaquin Valley Eastside.

Philosophical and social concepts and viewpoints, as well as economics, are involved in the over-all question of how much to charge farmers for irrigation water. This analysis does not undertake to deal with these issues. We do wish to point out, however, that variations in farm size and the range of alternative crops available to farmers in an area such as the San Joaquin Valley Eastside can present challenging problems to those responsible for deciding water costs and prices that farmers are required to pay. Thus a cost that effectively could price small operators and other less economically capable buyers out of the market still could be low enough, according to results in this study, to permit profitable operation for larger, and lower-cost, farmers. Lower water costs to make water available to the group previously excluded would make wider profit margins possible for the more economically capable farmers.

A further comment is appropriate about cotton in relationship to alternative sources of farm earnings in the San Joaquin Valley Eastside. Our analysis of the five individual farm sizes indicates that cotton acreage and production should expand to about double their 1956-1960 levels if price supports and acreage allotments were removed, but that total farm net returns-over-variable expenses would not differ greatly from those at present. This is because price supports are quite high compared with either the prices at

which farmers would find cotton relatively more profitable than other alternative crops (except for high-return specialty crops) or the world market for cotton. Here, again, market growth, both in cotton and in relatively profitable specialty crops, offers the best chance for higher farm earnings and improved ability to pay for irrigation water. Various studies suggest that progress toward such growth may occur during the period from 1960 to 1975.

APPENDIX TABLES

APPENDIX TABLE 1

Calculation Methods For Determining Annual Fixed Costs On Farm Property Or Capital Goods (illustrated by 70 drawbar horsepower tracklayer tractor).[a]

Non-cash costs

1. Interest (6% of average investment)

$$\left[\frac{\text{Original cost} + \text{salvage value}}{2}\right] 6/100 = \left[\frac{\$17,160 + \$2,402}{2}\right] 6/100 = \$587.$$

2. Depreciation

$$\frac{\text{Original cost} - \text{salvage value}}{\text{years on farm}} = \frac{\$17,160 - \$2,402}{10} = 1,476.$$

TOTAL $2,063.

Cash costs

1. Taxes

Assessment @ 35% of average investment = $3,423 x 6.5% levy = $222.

2. Insurance

Estimated @ 0.75% of average investment = 73.

TOTAL $295.

ALL FIXED COSTS $2,358.

a/ Fixed costs in this report include "overhead" costs that the farm operator incurs largely regardless of variations in the scope of his annual operations. A heavy proportion of these costs relate directly to land, machinery and other capital goods; some refer to such overhead as "cost of owning" such property, or, simply, as "capital costs." Another important category of fixed costs is those administrative expenses that are unavoidable in the function of managing, but that are difficult if not impossible to allocate to specific income-producing activities, or enterprises. Among this latter group are office expenses, organization dues, social security taxes, and, in this study, irrigation demand charges and district assessments.

APPENDIX TABLE 2

Calendar of Operations and Physical Inputs Per Acre; Cotton on Chino Clay Loam
Under 100 Percent Soil Moisture Depletion Practice

Dates and operations		Crew and equipment: Men	Power	Equipment	Acres per 9-hour day	Hours per acre: man	tractor	Materials
1		2	3	4	5	6	7	8
					160-acre farm			
PREPLANT								
Dec.	Disc (2X)	1	W-2 (35HP)	7'6" offset disc	18	1.00	1.00	
	Plow	1	W-2	2-way moldboard 2-16"	9	1.00	1.00	
Jan.	Landplane, contract			Contracted at $5.50 per acre				
	Chisel, contract			Contracted at $6.50 per acre				
	Disc (2X)	1	W-2	7'6" offset	18	1.00	1.00	
	List	1	W-2	4-R lister	36	.25	.25	
Feb.	Head ditch	1	W-2	24" ditcher	150	.06	.06	
	Preirrigate	1				1.00		
	Fill ditches	1	W-2	8' scraper	225	.04	.04	
March	Harrow and roll	1	W-2	30' spiketooth, 30' roller	30	.60	.60	
	Float	1	W-2	12' x 30'	30	.60	.60	
CULTURAL								
April	Plant	2	W-1 (25HP)	4-R planter	18	1.00	.50	25 lbs. seed per acre
	Cultivate	1	W-2	4-R cultivator	18	.50	.50	
	Cultivate and furrow	1	W-2	4-R	18	.50	.50	
May	Head ditch	1	W-2	24"	150	.06	.06	
	Irrigate	1				1.00		
	Fill ditches	1	W-2	8' scraper	225	.04	.04	
	Cultivate (2X)	1	W-2	4-R	18	1.00	1.00	
to	Head ditch	1	W-2	24"	150	.06	.06	
	Irrigate	1				1.00		
	Fill ditches	1	W-2	8' scraper	225	.04	.04	
	Cultivate (2X)	1	W-2	4-R	18	1.00	1.00	
	Head ditch	1	W-2	24"	150	.06	.06	
	Irrigate	1				1.00		
Aug.	Fill ditches	1	W-2	8' scraper	225	.04	.04	
	Cultivate (2X)	1	W-2	4-R	18	1.00	1.00	
	Head ditch	1	W-2	24"	150	.06	.06	
	Irrigate (4X)	1				4.00		Total water for irrigation = 3.90 acre-feet
	Fill ditches	1	W-2	8' scraper	225	.04	.04	
	Chop (2X), contract			Contracted at $15.00 per acre a/				
	Dust (2X), contract			Contracted at $7.50 per acre				1 gal. 25% DDT, 1-1/2 pint Systox
	Fertilize (2X), contract			Contracted at $3.50 per acre				125 lbs. N per acre
HARVEST								
Oct.-Nov.	Defoliate, contract			Contracted at $2.50 per acre				15 gal. diesel, 1 qt. dinitro
	Pick (2X)	2	W-2	1-R picker	3	3.00	3.00	
	Haul	1	Pickup 1/2 T	6-bale trailer	18	.50		
Dec.	Cut stalks	1	W-1	2-R cutter	36	.25	.25	
	TOTALS					18.70	12.70	
	Equipment service time (@ 1/9 operating hours)					1.40	--	
	ADJUSTED TOTALS					20.10	12.70	
					1,280-acre farm			
PREPLANT								
Dec.	Disc (2X)	1	TL-7	18' offset disc	45	.40	.40	
	Plow	1	TL-7	2-way moldboard 4-16"	18	.50	.50	
Jan.	Landplane	1	TL-7	12' x 60' landplane	30	.30	.30	
	Subsoil	1	TL-7	3-20" shanks	14	.67	.67	
	Disc	1	TL-1	12' offset disc	27	.30	.30	
	Furrow	1	W-2	4-R lister	18	.50	.50	
Feb.	Head ditch	1	TL-4	60" ditcher	300	.03	.03	
	Preirrigate	1			9	1.00		
	Fill ditches	1	TL-4	10' scraper	450	.02	.02	
March	Harrow and roll	1	TL-4	20' spiketooth, 20' roller	45	.20	.20	
	Float	1	TL-4	12' x 30'	45	.20	.20	
CULTURAL								
April	Plant	2	W-1	4-R planter	18	1.00	.50	25 lbs. seed per acre
	Cultivate	1	W-2	4-R cultivator	18	.50	.50	
May	Cultivate and furrow	1	W-2	4-R	18	.50	.50	
	Head ditch	1	TL-4	60" ditcher	300	.03	.03	
	Irrigate	1			9	1.00		
	Fill ditches	1	TL-4	10' scraper	450	.02	.02	
	Cultivate (2X)	1	W-2	4-R	18	1.00	1.00	
to	Head ditch	1	TL-4	60" ditcher	300	.03	.03	
	Irrigate	1			9	1.00		
	Fill ditches	1	TL-4	10' scraper	450	.02	.02	
	Cultivate (2X)	1	W-2	4-R	18	1.00	1.00	
	Head ditch	1	TL-4	60" ditcher	300	.03	.03	
	Irrigate	1			9	1.00		
Aug.	Fill ditches	1	TL-4	10' scraper	450	.02	.02	
	Cultivate (2X)	1	W-2	4-R	18	1.00	1.00	
	Head ditch	1	TL-4	60" ditcher	300	.03	.03	
	Irrigate (4X)	1			9	4.00		Total water for irrigation = 3.90 acre-feet
	Fill ditches	1	TL-4	10' scraper	450	.02	.02	
	Chop (2X), contract			Contracted @ $15.00 per acre a/				
	Fertilize (2X), contract			Contracted @ $3.50 per acre				125 lbs. N per acre
	Dust (2X), contract			Contracted @ $7.50 per acre				1 gal. 25% DDT, 1-1/2 pint Systox
HARVEST								
Oct.-Nov.	Defoliate, contract			Contracted @ $2.50 per acre				15 gal. diesel, 1 qt. dinitro
	Pick (2X)	2	H.P.	2-R S.P.	13	1.40	1.40	
	Haul	1	Pickup 1/2 T	5-bale trailer	18	.50		
Dec.	Cut stalks	1	W-1	4-R cutter	72	.25	.25	
	TOTALS					18.34	9.34	
	Equipment service time (@ 1/9 operating hours)					1.04	--	
	ADJUSTED TOTALS					19.38	9.34	

a/ Contract rates cover only services, excluding all materials costs.

APPENDIX TABLE 3

Variable Input Expenses Per Acre by Farm Sizes; Cotton--According to Soils and Irrigation Practices[a]

Input items	160-acre farm		320-acre farm		640-acre farm		1,280-acre farm	
	Chino c.l. 60%	Traver f.s.l. 100%	Chino c.l. 60%	Traver f.s.l. 100%	Chino c.l. 60%	Traver f.s.l. 100%	Chino c.l. 60%	Traver f.s.l. 100%
1	2	3	4	5	6	7	8	9
PREHARVEST	dollars, except as noted							
a. Power								
1) Light tractor (W1 - 25 HP)	.52	.52	.50	.50	1.04	1.04	.35	.35
2) Medium tractor (W2 - 35 HP)	7.95	7.95	4.61	4.61	4.31	4.31	4.32	4.32
3) Medium tracklayer (TL4 - 45 HP)	--	--	3.09	3.09	--	--	1.12	1.12
4) Heavy tracklayer (TL7 - 60 HP)	--	--	--	--	3.82	3.82	3.57	3.57
Total	8.47	8.47	8.20	8.20	9.17	9.17	9.36	9.36
b. Transport								
1) Pickup truck (1/2 ton)	2.63	2.63	4.40	4.40	2.48	2.48	2.48	2.48
c. Machinery[b]								
1) Plow	.50	.50	.50	.50	.50	.50	1.10	1.10
2) Chisel	6.50[c]	6.50[c]	.07	.07	.17	.17	.15	.15
3) Disc	.50	.50	.27	.27	.21	.21	.23[f]	.23[f]
4) Landplane	5.50[c]	5.50[c]	5.50[c]	5.50[c]	.12	.12	.15	.15
5) Spiketooth harrow	.03	.03	.01	.01	.01	.01	.02	.02
6) Roller	.12	.12	.04	.04	.04	.04	.02	.02
7) Planter	.10	.10	.10	.10	.10	.10	.10	.10
8) Cultivator)	.05	.05	.05	.05	.20	.20	.05	.05
9) Lister)	.05	.05	.05	.05	.20	.20	.05	.05
10) Ditcher	.03	.03	.02	.02	.02	.02	.02	.02
11) Scraper	.02	.02	.01	.01	.01	.01	.01	.01
12) Stalk cutter	.06	.06	.10	.10	.06	.06	.03	.03
13) Float	.09	.09	.03	.03	.03	.03	.03	.03
14) Lister[d]	.03	.03	.02	.02	.02	.02	.05	.05
15) Cultivator	.35	.35	.35	.35	.20	.20	.35	.35
Total	1.93[e]	1.93[e]	1.62[e]	1.62[e]	1.89	1.89	2.36	2.36
d. Labor								
1) Specialized	12.59	12.59	10.62	10.62	10.82	10.82	10.56	10.56
2) General	17.10	15.98	17.10	15.98	17.10	15.98	17.10	15.98
Total	29.69	28.57	27.72	26.60	27.92	26.80	27.66	26.54
e. Contract								
1) Fertilize - materials	17.82	16.80	17.62	16.60	15.85	14.95	15.85	14.95
application	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50
2) Dust - materials	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50
application	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50
3) Chop, weed and thin	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Total	68.32[g]	67.3[g]	61.62[g]	60.60[g]	54.35	53.45	54.35	53.45
f. Materials								
1) Seed	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75
g. Water								
1) For irrigation	13.43	12.82	13.43	12.82	13.43	12.82	13.43	12.82
h. Miscellaneous								
1) Labor and materials	4.50	4.50	4.50	4.50	5.00	5.00	5.50	5.50
Total preharvest	131.72	128.97	124.24	121.49	116.99	114.36	117.89	115.26
Interest on operating capital	4.61	4.51	4.35	4.25	4.09	4.00	4.13	4.03
Total preharvest plus interest	136.33	133.48	128.59	125.74	121.08	118.36	122.02	119.29
HARVEST (yield in bales)	2.29	1.90	2.29	1.90	2.29	1.90	2.29	1.90
a. Power								
1) cottonpicker	12.56[h]	12.56[h]	8.51[h]	8.51[h]	7.42	7.42	7.42	7.42
b. Transport								
1) Pickup truck	.39	.39	.38	.38	.62	.51	.38	.38
c. Machinery								
1) Cotton trailer	.25	.25	.25	.25	.25	.25	.25	.25
d. Labor								
1) Specialized	8.99	8.99	8.66	8.66	1.87	1.87	2.69	2.69
e. Contract								
1) Defoliate - material	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
application	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2) Ginning costs	34.35	28.50	34.35	28.50	34.35	28.50	34.35	28.50
Total	39.85	34.00	39.85	34.00	39.85	34.00	39.85	34.00
Total harvest	62.04	56.19	57.65	51.80	50.01	44.04	50.59	44.74
Total preharvest	136.33	133.48	128.59	125.74	121.08	118.36	122.02	119.29
Total variable inputs	198.37	189.67	186.24	177.54	171.09	162.40	172.61	164.03

a/ Irrigation practice includes 60 percent soil moisture depletion on Chino soil and 100 percent on Traver soil

b/ Machinery sizes vary with farm size.

c/ Per acre contract costs for these operations.

d/ Individual use.

e/ Totals exclude contracted operations (c/).

f/ Includes $.4 for 18' disc and $.09 for 12' disc.

g/ Total includes machinery operations contracted (footnote c/).

h/ Includes $2.81 for a tractor (W2) to pull the picker on 160 and $2.89 on 320.

APPENDIX TABLE 4

Variable Input Expenses and Net Returns Per Acre by Farm Sizes; Cotton--According to Soils and Irrigation Practices a/

Inputs by categories	160-acre farm		320-acre farm		640-acre farm		1,280-acre farm	
	Chino c.l. 60%	Traver f.s.l. 100%	Chino c.l. 60%	Traver f.s.l. 100%	Chino c.l. 60%	Traver f.s.l. 100%	Chino c.l. 60%	Traver f.s.l. 100%
1	2	3	4	5	6	7	8	9
	dollars, except as noted							
PREHARVEST								
a. Power	8.47	8.47	8.20	8.20	9.17	9.17	9.36	9.36
b. Transport	2.63	2.63	4.40	4.40	2.48	2.48	2.48	2.48
c. Machinery	1.93 b/	1.93 b/	1.62 b/	1.62 b/	1.89	1.89	2.36	2.36
d. Labor	29.69	28.57	27.72	26.60	27.92	26.80	27.66	26.54
e. Contract	68.32 c/	67.30 c/	61.62 c/	60.60	54.35	53.45	54.35	53.45
f. Materials	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75
g. Water	13.43	12.82	13.43	12.82	13.43	12.82	13.43	12.82
h. Miscellaneous	4.50	4.50	4.50	4.50	5.00	5.00	5.50	5.50
Total preharvest with interest	136.33	133.48	128.59	125.74	121.08	118.36	122.02	119.29
HARVEST (yield-bales)	2.29	1.90	2.29	1.90	2.29	1.90	2.29	1.90
a. Power	12.56 d/	12.56 d/	8.51 d/	8.51 d/	7.42	7.42	7.42	7.42
b. Transport	.39	.39	.38	.38	.62	.51	.38	.38
c. Machinery	.25	.25	.25	.25	.25	.25	.25	.25
d. Labor	8.99	8.99	8.66	8.66	1.87	1.87	2.69	2.69
e. Contract	39.85	34.00	39.85	34.00	39.85	34.00	39.85	34.00
Total harvest	62.04	56.19	57.65	51.80	50.01	44.05	50.59	44.74
Total variable inputs	198.37	189.67	186.24	177.54	171.09	162.40	172.61	164.03
Yield per acre	1,145 lb.	950 lb.	1,145 lb.	950 lb.	1,145 lb.	950 lb.	1,145 lb.	950 lb.
Price per pound	.33	.33	.33	.33	.33	.33	.33	.33
Gross receipts, lint	377.85	313.48	377.85	313.48	377.85	313.48	377.85	313.48
Gross receipts, seed	42.08	34.76	42.08	34.76	42.08	34.76	42.08	34.76
Total gross receipts	419.93	348.26	419.93	348.26	419.93	348.26	419.93	348.26
Net returns	221.56	158.59	233.69	170.72	248.84	185.86	247.32	184.23
Net returns above water e/	234.99	171.41	247.12	183.54	262.27	198.68	260.75	197.05

a/ Irrigation practice includes 60 percent soil moisture depletion on Chino soil and 100 percent on Traver soil.
b/ Totals exclude contracted operations.
c/ Total includes machinery operations contracted.
d/ Includes \$2.81 for tractor (W2) to pull the picker on 160 and \$2.89 on 320.
e/ Net returns with cost of irrigation water excluded from the expense.

APPENDIX TABLE 5

Variable Input Expenses and Net Returns Per Acre

Summary by Crops for All Farm Sizes;
Chino Clay Loam According to Irrigation Practices a/

Expense or receipt item	Alfalfa		Barley	Beans			Melons		Milo-double crop		Milo-single crop		Sugar beets	
	100%	80%	100%	100%	80%	80-100%	100%	80%	100%	80%	100%	80%	100%	80%
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
160-Acre Farm														
Preharvest inputs	61.20	61.94	46.35	54.01	55.79	55.03	136.02	138.67	44.37	46.89	46.87	48.33	142.77	143.28
Harvest inputs	47.77	49.77	10.71	40.59	42.64	41.42	351.00	374.40	12.96	13.60	14.08	14.80	56.16	60.06
Total inputs	108.97	111.71	57.06	94.60	98.43	96.45	487.02	513.07	57.33	60.49	60.95	63.13	198.93	203.34
Yield per acre	7.19T	7.61T	31.40cwt	19.12cwt	20.40cwt	19.64cwt	180.00crts.	192.00crts.	44.80cwt	48.00cwt	44.80cwt	48.00cwt	21.60T	23.10T
Price per unit	25.57/T	25.57/T	2.16/cwt	8.53/cwt	8.53/cwt	8.53/cwt	3.80/crt.	3.80/crt.	2.09/cwt	2.09/cwt	2.09/cwt	2.09/cwt	13.25/T	13.25/T
Gross receipts	183.85	194.59	67.82	163.09	174.01	167.53	684.00	729.60	93.63	100.32	93.63	100.32	286.20	306.08
Net returns	74.88	82.88	10.76	68.49	75.58	71.08	196.98	216.53	36.30	39.83	32.68	37.19	87.27	102.74
Net returns above water b/	93.01	101.34	16.26	74.17	82.06	77.22	204.62	225.36	44.47	49.14	40.81	46.43	102.91	118.60
320-Acre Farm														
Preharvest inputs	61.42	62.17	42.75	50.28	52.09	51.34	127.60	130.25	43.32	45.85	46.78	48.24	133.54	134.05
Harvest inputs	47.23	49.23	10.65	40.59	42.64	41.42	351.00	374.40	12.96	13.60	14.08	14.80	56.16	60.06
Total inputs	108.65	111.40	53.40	90.87	94.73	92.76	478.60	504.65	56.28	59.45	60.86	63.04	189.70	194.11
Yield per acre	7.19T	7.61T	31.40cwt	19.12cwt	20.40cwt.	19.64cwt	180.00crts.	192.00crts.	44.80cwt	48.00cwt	44.80cwt	48.00cwt	21.60T	23.10T
Price per unit	25.57/T	25.57/T	2.16/cwt	8.53/cwt	8.53/cwt	8.53/cwt	3.80/crt.	3.80/crt.	2.09/cwt	2.09/cwt	2.09/cwt	2.09/cwt	13.25/T	13.25/T
Gross receipts	183.85	194.59	67.82	163.09	174.01	167.53	684.00	729.60	93.63	100.32	93.63	100.32	286.20	306.08
Net returns	75.19	83.19	14.42	72.22	79.28	74.77	205.40	224.95	37.35	40.87	32.77	37.28	96.50	111.97
Net returns above water b/	93.32	101.65	19.92	77.90	85.76	80.91	213.04	233.78	45.52	50.18	40.90	46.52	112.14	127.83
640-Acre Farm														
Preharvest inputs	60.25	61.00	38.59	48.68	50.47	49.71	121.22	123.87	40.88	43.34	44.86	46.32	127.01	127.52
Harvest inputs	49.22	51.54	10.71	40.59	42.64	41.42	351.00	374.40	12.96	13.60	12.96	13.60	56.16	60.06
Total inputs	109.47	112.54	49.30	89.27	93.11	91.13	472.22	498.27	53.84	56.94	57.82	59.92	183.17	187.58
Yield per acre	7.19T	7.61T	31.40cwt	19.12cwt	20.40cwt	19.64cwt	180.00crts.	192.00crts.	44.80cwt	48.00cwt	44.80cwt	48.00cwt	21.60T	23.10T
Price per unit	25.57/T	25.57/T	2.16/cwt	8.53/cwt	8.53/cwt	8.53/cwt	3.80/crt.	3.80/crt.	2.09/cwt	2.09/cwt	2.09/cwt	2.09/cwt	13.25/T	13.25/T
Gross receipts	183.85	194.59	67.82	163.09	174.01	167.53	684.00	729.60	93.63	100.32	93.63	100.32	286.20	206.08
Net returns	74.38	82.05	18.52	73.82	80.90	76.40	211.78	231.33	39.85	43.38	35.81	40.40	103.03	118.50
Net returns above water b/	92.52	100.52	24.02	79.50	87.38	82.54	219.42	240.16	48.02	52.69	43.94	49.64	118.67	134.36
1,280-Acre Farm														
Preharvest inputs	60.56	61.31	38.54	49.50	51.29	50.53	123.11	125.76	41.53	44.06	42.57	44.03	126.23	126.74
Harvest inputs	24.36	24.68	5.74	40.59	42.64	41.42	351.00	374.40	7.08	7.40	7.08	7.40	29.60	31.25
Total inputs	84.92	85.99	44.28	90.09	93.93	91.95	474.11	500.16	48.61	51.46	49.65	51.43	155.83	157.99
Yield per acre	7.19T	7.61T	31.40cwt	19.12cwt	20.40cwt	19.64cwt	180.00crts.	192.00crts.	44.80cwt	48.00cwt	44.80cwt	48.00cwt	21.60T	23.10T
Price per unit	25.57/T	25.57/T	2.16/cwt	8.53/cwt	8.53/cwt	8.53/cwt	3.80crt.	3.80/crt.	2.09/cwt	2.09/cwt	2.09/cwt	2.09/cwt	13.25/T	13.25/T
Gross receipts	183.85	194.59	67.82	163.09	174.01	167.53	684.00	729.60	93.63	100.32	93.63	100.32	286.20	306.08
Net returns	98.93	108.60	23.54	73.00	80.08	75.58	209.89	229.44	45.02	48.86	43.98	48.89	130.37	148.09
Net returns above water b/	117.06	127.06	29.04	78.68	86.56	81.72	217.53	238.27	53.19	58.17	52.11	58.13	146.01	163.95

a/ Irrigation practices include three levels of soil moisture depletion (60, 80, and 100%) before reirrigating.

b/ Net returns with the cost of irrigation water excluded.

DIVISION OF AGRICULTURAL SCIENCES
UNIVERSITY OF CALIFORNIA

Economics of On-Farm Irrigation Water Availability and Cost, and Related Farm Adjustments

4. Intravalley Variations in Relation to Resource Use, Earnings, and Adjustments in the San Joaquin Valley Cotton Area

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and
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CALIFORNIA AGRICULTURAL EXPERIMENT STATION
GIANNINI FOUNDATION OF AGRICULTURAL ECONOMICS

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FOREWORD

We conducted this report, the fourth and final in the series presenting the results of an investigation of on-farm irrigation for cotton-general crop farms, under two California Agricultural Experiment Station Projects, Numbers 1641 and H-1863.[1/] The University of California Water Resources Center contributed a large proportion of the funds for the latter project, which also is the state contributing project under Western Regional Research Project W-70.

Our thanks go to many agencies and individuals without whose most generous cooperation neither this report nor others in the series would have been possible. Among these we cite, particularly, colleagues in the University of California, Department of Irrigation: R. M. Hagan, Y. Vaadia, D. W. Henderson, L. J. Booher, and C. E. Houston at Davis, and John Stockton at the Shafter Cotton Field Station. Others providing important assistance include L. H. Richards of the U.S. Salinity Laboratory at Riverside, and farm advisors in the study-area counties: L. K. Stromberg, G. V. Ferry, A. G. George, O. D. McCutcheon, E. A. Libra, and C. E. Johnson.

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Many agencies and companies contributed importantly, thus Pacific Gas and Electric, and Southern California Edison, the major power companies serving the San Joaquin Valley, authorized us to use well-test data previously released to the U.S. Geological Survey. The latter agency aided greatly in this procedure by making available photostatic copies of office records. The California Regional Water Pollution Control Board made well-driller reports available to us (data for individual reports are not identified in order to keep both of these sets of information confidential). The California Department of Water Resources also assisted importantly in these studies by furnishing maps, reports, and other information, as did the U.S. Bureau of Reclamation. The California Irrigation Districts Association, many individual irrigation districts, and various manufacturers and distributors of irrigation pumps and equipment provided much valuable assistance in the form of factual data and interpretation.

1/ We cite other publications in this series in footnote 1/ on page 1.

SUMMARY

The investigations reported here used linear programming and budget analysis procedures to examine how variations in irrigation water quantities available on 640-acre farms, and in the variable cost components of this water, affect farm resource use and returns in four subareas of the cotton-growing San Joaquin Valley. Four 640-acre cotton-general farm models, synthesized to typify conditions in Upper, Eastside, Westside, and Central study areas, respectively, are analyzed in detail. This 640-acre size is important in all subareas except Westside where much larger farms predominate. All economic interpretations relate to a predetermined set of price and cost conditions calculated and estimated from sample data and official sources to represent the study period, 1956-1960. Price-cost relationships, net returns-over-variable expenses, "break-even" prices, profits, and other measures, all relate, therefore, to these predetermined prices and costs. We claim no validity for our findings except within this framework.

Physical, institutional, and economic conditions in the four subareas vary widely; important differences exist in soils, climatic characteristics, and water availability and/or costs. According to county wide cotton yields, Kern County ranks first, followed by Fresno, Tulare, and Madera counties. Water supplies are most plentiful in ratio to irrigable land in Central, and the shortest in Westside (currently almost entirely dependent upon ground water with extreme pumping lifts that tend to increase each year).

We evaluated three different cropping systems for Upper, Eastside, and Westside, but only one for Central. System A includes cantaloups (potatoes in Upper) and sugar beets as specialty crops, plus Blackeye beans, alfalfa hay, and grains; System B excludes cantaloups (or potatoes); System C, found in all subareas, excludes both cantaloups (or potatoes) and sugar beets.

Cotton is decidedly the most profitable crop on the better soils in all subareas. With few exceptions, this is true for each of three soil-crop-irrigation practice combinations studied for the various alternative crops (wet, medium, and dry irrigation treatments). Actual net returns-over-variable expenses (other than water costs) for this crop vary in amount from $158 per acre in Central to $358 in Upper for the highest return soil-crop irrigation practice. Yield differences largely explain these variations.

Melons (or potatoes) rank next to cotton in net returns in the subareas where grown, with sugar beets (or alfalfa hay) usually following. Blackeye beans

is the next most profitable crop in all subareas (outranking sugar beets on Grade II soil in Westside) and the grains follow. In general, the grains (barley and/or milo; corn is important only in Central) leave little net returns-above-variable expenses to apply against fixed costs.

Optimum linear programming solutions provide comparisons among the various farming systems in the four subareas at "break-even" prices. There are substantial differences among the four <u>subareas</u> for a particular cropping system, and among the <u>systems</u> in each subarea:

1. For System C, as irrigation water prices vary from zero to about $32.00 per acre-foot, break-even prices for this critical input are $17.50 for the ground-plus-surface water combination in Westside, but only $4.75 in Central. The ground-water-only unit in Westside and the Upper model agree quite closely in their break-even prices -- $14.00 and $13.00, respectively, with Eastside's $10.00 per acre-foot figure next (more than double the one for Central).

2. Cropping System A shows distinct earning advantages in the three subareas where this combination was tested. In Upper the break-even price is $20.75 per acre-foot for System A, or $8.00 per acre-foot above that for System C. The B cropping combination shows some gains, but a smaller earnings advantage over System C than A.

3. Total amounts of water associated with break-even total farm net returns-over-variable expenses also vary widely: 850 to 875 acre-feet in Upper and Westside versus 1,950 acre-feet in Central. These comparisons are according to cropping System C. The break-even quantities are smaller for systems including high-value specialty crops: 760 acre-feet in Westside, 825 in Upper, and 1,025 in Eastside.

4. The quantities of irrigation water at which operators can maximize total farm net returns-over-variable expenses under conditions of this study also differ markedly among subareas, as do the magnitudes of the net returns. Upper shows net returns of about $100,000 for System C at 4,463 acre-feet, and Central about $63,000 net returns at 3,500 acre-feet of irrigation water; the other two subareas are in between the two extremes, Westside (ground-plus-surface water unit) $90,000 at 2,500 acre-feet, and Eastside $84,000 at 2,760 acre-feet. Fixed costs have <u>not</u> been deducted in arriving at these total farm net returns values.

5. In each subarea, cotton offers the highest net returns for irrigation water for initial water increments up to the maximum 200-acre allotment. Under the driest irrigation treatment, however, other crops can increase total farm net returns. Usually Blackeye beans, followed by alfalfa hay, are the next two crops to enter the cropping plan. A common pattern of adjustments commonly leads to maximum net returns-over-variable expenses: first, introducing Blackeye beans into the cropping system, second, bringing lower quality land into production, third shifting from the drier to wetter irrigation practices, and fourth, adding alfalfa hay.

6. Added net returns-over-variable expenses per acre-foot of water applied are greatest in all subareas for the initial water increments (used to produce cotton) and decline sharply with later quantities added. These values per acre-foot for the initial increments are as follows: Upper $101, Westside $90, Eastside $59, and Central $43.

7. Adjustments on these models to obtain maximum total farm net returns-over-variable expenses as water costs rise, are similar in all subareas: first, reducing alfalfa acreage and increasing Blackeye beans, second, shifting to drier irrigation treatments for alfalfa and/or cotton, third, eliminating alfalfa and leaving some (lower grade) land idle, fourth, growing cotton, with or without some Blackeye beans, and leaving all other land idle.

8. Estimated total farm profit for Upper ($62,840) is almost double that for Central ($33,140) with values for the other two subareas between these extremes. Rates earned on investments are 9.91 percent for Upper, 8.69 percent for Central, and 6.50 for Westside (ground-water-only unit). Management income (interest at 6 percent on average total farm investments already deducted) varies from $24,780 for Upper to $10,270 for Central. These latter two measures depend heavily on the values we assumed for land which are only estimates. The measures, therefore, are much more useful for suggesting <u>differences</u> among subareas than to indicate <u>actual</u> earnings levels. Cotton price supports and acreage limitations affect incomes importantly in each subarea.

9. Cotton would be more profitable than other available alternatives at lint prices of 20.0 cents per pound in all subareas except Central, where 25.1 cents is the critical price. Without allotments, slight rises in prices would make it profitable to put all Grade I soil into cotton. Without Government price supports and acreage controls, San Joaquin Valley farmers would profit by expanding cotton acreage and production sharply. Central would be at a disadvantage as compared with the other subareas; farmers here might find cotton production less advantageous than other alternative crops at lint prices high enough to encourage heavy expansion in the other three subareas.

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ECONOMICS OF ON-FARM IRRIGATION WATER AVAILABILITY AND COST, AND RELATED FARM ADJUSTMENTS

4. Intravalley Variations in Relation to Resource Use, Earnings, and Adjustments in the San Joaquin Valley Cotton Area

Trimble R. Hedges* and Charles V. Moore**

SUBAREA VARIATIONS INFLUENCE ON-FARM IRRIGATION PROBLEMS

This is a Comparative Analysis of Farms by Geographic Subareas

This report deals with organization, adjustment, and earnings problems arising from variations in irrigation water availability and costs on San Joaquin Valley cotton-general crop farms. It differs from others in the series on irrigation economics in that it examines variations among subareas with respect to how differences in water quantities and costs affect farm performance.1/

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1/ Other Giannini Foundation Research Reports in this series are as follows: Hedges, Trimble R., and Charles V. Moore, Economics of On-Farm Irrigation Water Availability and Cost and Related Farm Adjustments. 1. Enterprise Choices, Resource Allocations, and Earnings on 640-Acre General Crop Farms on the San Joaquin Valley Eastside, California Agricultural Experiment Station, Giannini Foundation Research Report No. 257, 1962; Moore and Hedges, Economics of On-Farm Irrigation Water Availability and Cost and Related Farm Adjustments. 2. Farm Size in Relation to Resource Use, Earnings, and Adjustments on the San Joaquin Valley Eastside, California Agricultural Experiment Station, Giannini Foundation Research Report No. 263, 1962; Moore and Hedges, Economics of On-Farm Irrigation Water Availability and Cost and Related Farm Adjustments. 3. Some Aggregate Aspects of Farmer Demand for Irrigation Water and Production Response on the San Joaquin Valley Eastside, California Agricultural Experiment Station, Giannini Foundation Research Report No. 261, 1962; Moore and Hedges, Some Characteristics of Farm Irrigation Supplies in the San Joaquin Valley, California Agricultural Experiment Station, Giannini Foundation Research Report No. 258, 1962.

The study area includes the entire cotton-growing portion of the San Joaquin Valley from Merced County south, through and including Kern, whereas the earlier reports dealt only with the San Joaquin Valley Eastside (see Figure 1).

The over-all objective in the analyses reported here is to identify and measure how variations among four defined subareas in the San Joaquin Valley cotton area affect irrigation economics on 640-acre farms. Specifically, these investigations seek to identify and measure differentials among subareas in the manner and degree to which variations, first, in water costs and, second, in water quantities, influence water use, crop choices and resource allocations, farm production, gross receipts, and earnings for cotton-general crop farms. Four cotton-general crop farms, synthesized as "typical" of the study subareas, are used in comparative analyses directed to this over-all objective. The four subareas and counties that furnished most of the data used in synthesizing the respective models, are as follows: Upper San Joaquin Valley (Kern County), San Joaquin Valley Eastside (Tulare County), San Joaquin Valley Westside (western Fresno County), and Central San Joaquin Valley (Madera County).

Certain specific subobjectives underlie the over-all objective specified for this study. Several, primarily of procedural nature, are quite similar to those for the first study reported in this series.[1/] These subobjectives concern themselves primarily with, (a) constructing input-output models for irrigation water use, (b) establishing the source and cost characteristics of farm irrigation water supply, (c) synthesizing farm models to typify modal characteristics, (d) constructing complete input-output models for evaluating farm performance, (e) identifying economic choice criteria for managerial decisions directed to maximizing farm profits, (f) applying effective measurement techniques and data to evaluate how varying water price and quantity conditions affect farm performance, and, (g) exploring the opportunities for adjusting farm organizational and operational characteristics in response to varying water price and supply conditions. Four interrelated procedures are particularly important in these investigations:

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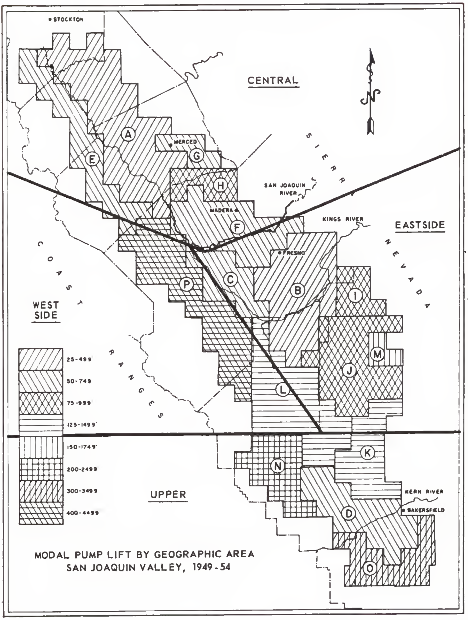
1/ Hedges and Moore, Economics of On-Farm . . . . 1. Enterprise Choices, Resource . . . , pp. 6-7.

FIGURE 1

Subareas in the San Joaquin Valley Cotton Areas and Modal Pump Lifts by Specified Class Intervals



Pumping Lifts Represent One Characteristic in Which Cotton Subareas Differ; They Tend to Increase From North to South and East to West

1. Identifying the variations among subareas in quantity and quality of agricultural resources available, and in governing economic and institutional conditions and forces;

2. Assuring that the synthesized cotton-general crop farms used as models to typify the respective subareas actually do reflect the important variations among them;

3. Measuring differential impacts of variations among subareas in how water cost and quantity conditions affect water use, crop choice and resource allocations, and farm earnings performance; and,

4. Determining differences among the four subareas in possible adjustments appropriate to changes in water cost or quantity.

Linear Programming and Budgeting are the Principal Analytical Techniques

We use linear programming[1/] in this study to calculate optimum cropping plans for a wide variety of possible water cost and quantity conditions. These latter provide normative solutions (i.e., what farmers should do), rather than positive solutions (what farmers actually are doing) under a specified (single) set of product sale prices and input prices and costs. Further, they assume that operators have complete knowledge of all relevant prices and costs prior to the planting season. Our analysis, therefore, does not take into account possible actions operators may take as adjustments to uncertainties in prices, weather, and/or other critical phenomena. We emphasize the importance of the above reference to "a specified single set of product sales prices and input prices and costs." We claim no relevance for our findings beyond these specified price conditions. Later references to "break-even points," "net returns-over-variable expenses," "profits," and other key terms and measures of relationships appearing in the analyses reported here are applicable only within this same set of conditions. The reader should keep these limitations in mind, and interpret our results accordingly.

The basic over-all procedure used in this report is to calculate optimum cropping plans for a farm model, as changes occur in one variable at a time.

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1/ Various writers have presented thorough treatments of linear programming methodology. See, for example, Heady, Earl O., and Wilfred Candler, Linear Programming Methods, Ames: Iowa State University Press, 1958; Garvin, Walter W., Introduction to Linear Programming, McGraw-Hill Book Company, New York, 1960. See also other reports in this series dealing with economics of on-farm irrigation, particularly Hedges and Moore, Economics of On-Farm . . . . 1. Enterprise Choices, Resource . . . , pp. 37-41.

First, we obtain solutions with the price (variable cost) of irrigation water changing from zero, progressively, to $32 per acre-foot. For this analysis all other prices, costs, and resource supplies remain constant at predetermined levels.

Second, we vary the annual quantities of water available continuously from zero to predetermined maximum levels, all costs and prices (including water) remaining constant.

In the third analysis, we explore the impact of various cotton lint prices on farm income and, in turn, farmer's ability to pay for irrigation water. As during the two previous analyses, all other prices and resource supplies except cotton acreage allotments remain constant at predetermined levels.

An earlier report in this series outlines in detail and discusses at some length the major components of this over-all procedure.[1/] Thus we do not repeat this presentation here. Some amplification and explanation, as necessary regarding certain methodological and procedural matters, does appear in subsequent analysis and discussion.

Linear Programming Considers Two Kinds of Constraints and Various Income Activities in This Study

Soil quantities by quality grades and irrigation water quantities represent the principal physical resource constraints in this study.

Cotton acreage allotments, sugar beet proportionate shares, the necessity to obtain contracts for such specialty crops as cantaloups, and other considerations, also operate to limit farm operators' freedom in choosing crops and/or allocating land to individual crops, once chosen. Our analyses recognize these restrictions and include them as constraints. This is true whether they reflect formal regulations by established institutions (such as U.S. Department of Agriculture cotton acreage allotments), or less official restrictions (such as the maximum acreage for which a melon shipper is willing to contract with a grower, due to price uncertainty or other forces). In summary, then, the constraints in the linear programming analyses were as follows:

Resource Constraints.--

1. Acres of irrigable land in each soil grade (see Figure 2)

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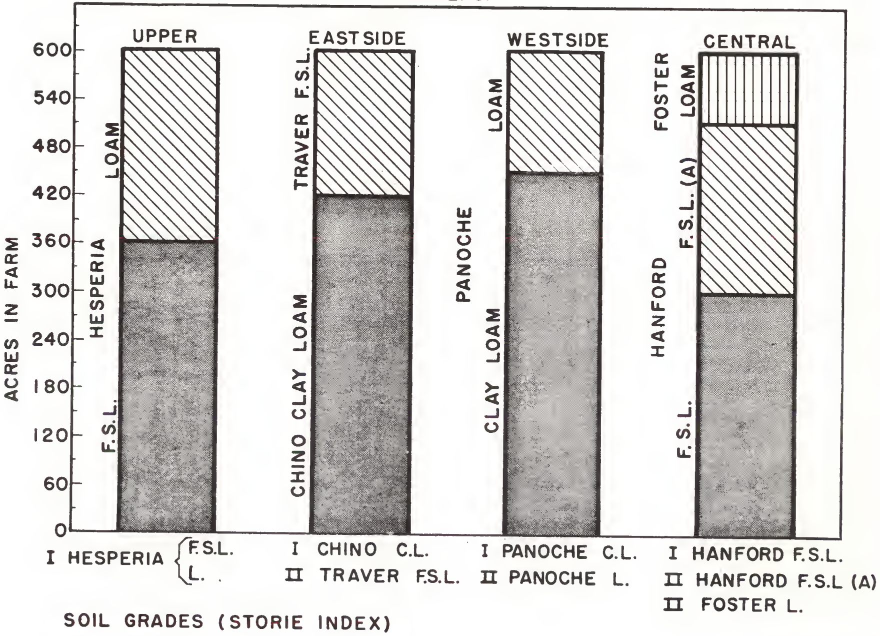
1/ Hedges and Moore, Economics of On-Farm . . . . 1. Enterprise Choices, Resource . . . , pp. 25-36.

FIGURE-2

IRRIGABLE FARM LAND BY SOIL GRADES; 640-ACRE FARM MODELS IN FOUR SAN JOAQUIN VALLEY SUBAREAS.



2. Irrigation water quantities available for the season as a whole and for each irrigation period. 1/

Economic and Institutional Constraints.--

1. Federal acreage allotments limit cotton acres to not more than 33 percent of irrigable land, according to conditions in this study;

2. Proportionate shares for sugar beets represent a maximum of 12 percent of irrigable land;

3. Necessity for marketing contracts limits cantaloup acres to 15 percent of irrigable land; and

4. Farmers voluntarily limit potato acres to not more than 20 percent and Blackeye bean acres to not more than 26 percent of irrigable land, due to market and price uncertainty.

The first two of the latter constraints reflect specific Government programs with definite regulations in effect during the study period; the latter two are procedural assumptions.

Income-Producing Activities.--The list of alternative crops and the restrictions (constraints) affecting farmer decisions in planning cropping programs with these crops in each subarea establish the framework for linear programming analysis. Combinations of crops, soils, and specified irrigation treatments become income-producing activities. The restrictions govern the choices of these activities in seeking optimum solutions for maximizing total farm net returns-over-variable expenses, as the critical independent variable (water price, water quantities available, or cotton lint prices) assumes different values within a predetermined range.

Preliminary screening indicated that 11 crops or crop combinations were sufficiently important in one or more subareas to include in the analyses. As indicated in the following summary, however, not all were important in each subarea:

Upper, cotton, potatoes, alfalfa hay, beans, grain sorghum, barley-sorghum, and barley, total 11;

Eastside, cotton, cantaloups, alfalfa hay, beans, grain sorghum, field corn, barley-sorghum, barley, and sugar beets, total 9;

1/ Water quantities available for the farm model representing the Central San Joaquin Valley were sufficiently large that the analysis for this subarea does not include irrigation water constraints.

Westside, cotton, cantaloups, alfalfa hay, alfalfa seed, beans, grain sorghum, barley-sorghum, barley, and sugar beets, total 9; and

Central, cotton, alfalfa hay, beans, grain sorghum, barley-sorghum, and barley, total 6.

The total number of income-producing activities in each subarea greatly exceeds the number of crops or double-crop combinations studied. Thus totals of these activities by subareas were as follows: Upper 31, Eastside and Westside 37 each, and Central 22. This overrun of income activities as compared with crops was due to the fact that each alternative crop enterprise may generate two or more income activities, in combinations with different soil and irrigation treatments. We considered four possible irrigation treatments and two soils in each of three subareas (Upper, Eastside, and Westside) and three each for treatments and soils in Central.

Specialty crops such as cantaloups and sugar beets vary among subareas in their relative importance. Such variations are evident in terms of total acres grown, number of farmers growing these crops regularly, and the percentages that farmers growing these crops represent of all cotton-general crop farms in the subarea. One or the other of the two specialty crops included in this analysis (cantaloups and potatoes) is relatively more important in Upper and Westside than in either of the other two subareas. Even in Upper and Westside, however, a relatively small percentage of all farmers grow such crops -- these and other specialty crops, therefore, represent an alternative farming system available to the few growers favorably situated to produce them, rather than an alternative generally available to all farmers. Somewhat similar statements apply to sugar beets and to Blackeye beans in the subareas where these crops represent alternative crops. As a result of these variations, applying in one form or another to all four subareas, this analysis considers three alternative cropping systems. These are identified as follows:

1. System A. Includes all alternative crops for each subarea;

2. System B. Excludes potatoes in Upper and cantaloups in the remaining subareas; and,

3. System C. Excludes potatoes and sugar beets in Upper and cantaloups and sugar beets in the remaining subareas. 1/

The group of alternative crops available to farmers in Central for planning their cropping programs does not include either cantaloups or sugar beets; System C (excluding cantaloups and sugar beets) is the only one analyzed for this subarea. As a result, all comparisons among the four subareas studied, necessarily, must be according to cropping System C. Within all subareas, except Central, it was possible to compare the performance of all three groups of alternative crops (Systems A, B, and C).

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1/ Major terms relating to farm models appearing in this report, and their definitions, are as follows:

Cropping System - detailed cropping organization for a Farm Model.
Farm Model - synthesized Farming System, based on modal farm characteristic data for a particular geographic subarea.
Farming System - detailed organization, methods of operation, and practices used on a Farm Model.
Subarea - a segment of a major geographic area, such as the San Joaquin Valley, selected for study.
Irrigation Practice - technique or method used in irrigation, identified in this study by the depletion level for available soil moisture prior to irrigation.

Variable Expenses (Costs) - sum of annual cash operating expenses, plus unpaid family (operator's) labor (see Appendix Table A-5). This item may appear as Variable Expenses (Costs) per Acre for a single crop, or as Farm Variable Expenses (Costs) representing the total for an entire farm.
Fixed Costs - sum of annual cash and noncash costs for using capital items and for general costs not readily allocated to specific enterprises (see Appendix Table A-1).
Gross Receipts - sum of annual receipts from sales of farm crops.
Net Returns-Over-Variable Expenses (Costs) - Gross Receipts minus Variable Expenses (Costs) (see Appendix Table A-5). This item may appear as Net Returns-Over-Variable Expenses (Costs) for a single crop acre, or as Farm Net Returns-Over-Variable Expenses (Costs) representing the total for an entire farm.
Net Farm Income - net cash income plus (or minus) inventory changes on noncapital items and minus noncash fixed costs (not including interest on investment). Any unpaid labor contributed by the farm operator is not included in the farm expenses.
Profit (Capital and Management Income) - Net Farm Income minus the value of any unpaid labor (including operator's).
Management Income - Profit less 6 percent on the total farm capital. The residual (and it may be negative) is payment for the operator's managerial ability and services.
Rate Earned - Profit (Capital and Management Income) expressed as a percentage of the farm capital.

FOUR 640-ACRE COTTON-GENERAL CROP FARMS SERVE AS MODELS FOR THIS STUDY

Farm Models Reflect Original and Secondary Data for Four Subareas

The kinds of information and the sources providing it, the procedures used to determine the characteristics for farm models, and the reasons for choosing these particular procedures appear, together with a full discussion, in an earlier report.[1/] We, therefore, do not repeat this standard information in detail here; we say, instead, that the 640-acre farm model for each subarea is a synthesized operating unit intended to typify modal organizational and operational characteristics for a predominantly important group of farms in that subarea, considering soils and other natural resources, total acreages involved, and numbers of farms of all sizes in such groups. Thus the synthesized models do not appear here as representative or "typical" of all farms in their respective subareas (counties); each does reflect an important group under common physical, economic, and institutional conditions. The data used in synthesizing these models typify the conditions in the several study areas during the study period, and were obtained through interviews and from secondary (published) sources. Inasmuch as we used modes, rather than means, as measures of central tendency in summarizing these data, we believe that the models do reflect accurately the predominant characteristics and prevailing conditions for the farm population groups studied.[2/]

The study period, as for other reports in this series, covers the years 1956-1960. Price and cost conditions generally reflect this period, though analytical procedures used permitted us to examine what the results would be if one particular price, e.g., water variable costs, varies leaving other prices and cost items within this framework unchanged.

Three models employed in this analysis, those for Upper, Eastside, and Central, are synthesized to reflect directly the study period conditions in their respective subareas, as indicated in the previous paragraph. This is distinctly not true, however, for the Westside. Our model identified as Westside, ground-plus-surface water, reflects soils and climatic characteristics as they exist in the subarea, but includes substantial quantities of surface water at prices estimated to be consistent with those anticipated under the joint California-United States San Luis irrigation project. We also include a comparison model

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1/ Hedges and Moore, Economics of On-Farm . . . . 1. Enterprise Choices, Resource . . . .

2/ See Appendix Table A-5 for product sales prices and yields.

in the Westside to reflect the conditions that would prevail on a Westside 640-acre farm, if such units existed; this is the Westside, ground-water-only, model.

Adequate data for inputs, crop yields, and prices or cost rates for the various items involved were available for Westside. Data for the other three subareas aided in rounding out farm machinery and equipment complements and other organizational characteristics for these models. Inevitably, the 640-acre units for Westside represent a much more artificial -- and less currently realistic -- model than those for the other three subareas. This variation is unavoidable under existing and anticipated circumstances. A major change in availability of the water resource (and in the terms under which farmers may obtain it) is expected to stimulate drastic shifts in farm size, land-use patterns, farm organizational characteristics, production patterns, and, perhaps, ownership on the Westside.

Synthesized Resources for the Farm Models Vary among Subareas

Soils Reflect Conditions for a Sizable Portion of Each Study Area.--Among the four models, the one for Upper with its entire 602 acres of tillable land classed in two different phases of Grade I soil (Hesperia series), according to the Storie Index, has the most productive land.1/ Westside ranks next with 75 percent Grade I and 25 percent Grade II; the Eastside model ranks slightly lower with 70 percent Grade I and 30 percent Grade II; the Central farm has 50 percent Grade I, with the remainder divided about two-thirds Grade II and one-third Grade III (see Figure 2). The details for soil resource distribution according to farm models in the four subareas appear in the following text table (based upon official soil survey reports). All models show the same proportion of total land cultivation, each including 38 acres in roads, ditches, and other nontillable uses.

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1/ Storie, R. E., Index for Rating the Agricultural Value of Soils, California Agricultural Experiment Station, Bul. 556, 1933.

Unit	Soils by Grade in Four Models[a]			
	Upper	Eastside	Westside	Central
	acres			
Arable (Irrigable)				
Grade I	361	421	451	301
	241	--[b]	--	--
Grade II	--	181	151	211
Grade III	--	--	--	90
Other	38	38	38	38
TOTAL	640	640	640	640

a/ According to the Storie Index.
b/ Upper included Grade I soils in each of two distinct series.
Source: Soil Survey reports (see Table 3 , page 22).

Each of these soil resource patterns fairly well represents the dominant agricultural production area for the county studied in that particular subarea; therefore, it cannot represent all farms in that county. Thus the analytical model for the Upper San Joaquin Valley, with 100 percent of its soil classed Grade I, definitely does not typify all cotton-general crop farms in Kern County. Rather, it applies to the highly productive area in the McFarland-Wasco-Shafter locality where land in farms quite commonly is of this quality. The Eastside model agrees quite closely in soil resources with the cotton farms in the western portion of Tulare County. This model also may reflect more accurately than the Upper model the soil resources available to farm operators in cotton-general crop farming localities for Kern County, other than the McFarland-Shafter-Wasco locality.

Again, the soils listed for the Westside model reflect the resources typical of the major belt of Panoche series soils in the central and western portions of the subarea. These soils are more productive than the heavier ones lying to the east of them. Soil resources for the Central model are reasonably typical of those in the cotton-general crop farming area, where most farms include soils of several grades. These resources are superior to the soils in other portions of Madera and Merced counties where Grade III and lower soils prevail, and the land is suitable primarily for winter grains and pastures.

Considering all four analytical models, these synthesized farms fairly well typify the wide range of variations in soil resources within the San Joaquin

Valley cotton-producing area. The model for Central, including three soil grades and with only half of the land classed Grade I, is markedly similar in soils to many farms in other subareas whose proportion of Grade I land falls short of that for the other three models.

Water Costs and Quantities Available Vary among the Four Models.--The total water available for each of the four synthesized farm units includes both underground and surface sources, with the latter representing the largest (60 percent) proportion of the total in Westside (see Figure 3). This subarea also has the most limited supply (about 2,750 acre-feet) while Upper, with nearly 5,400 acre-feet, has the most ample quantities available. Details on annual quantities, and the relative proportions that ground and surface water represent in these totals, appear in the following text table. Seasonal fluctuations in quantities are least important in Central with the other three subareas ranking as follows: Upper, Eastside, and Westside (see Figure 3). Again, with water quantities, as with soils, the amounts specified for the subarea models do not represent all farms in the respective counties, although they are typical of a large group of farms.

Unit	Acre-Feet of Water Available per Farm Model			
	Upper	Eastside	Westside	Central
Ground[a/]	4,625.0	4,586.0	1,161.0	4,481.0
Surface	806.0	348.0	1,593.0	664.0
TOTAL	5,431.0	4,934.0	2,753.0	5,145.0
Acre-feet per acre	9.0	8.0	4.5	8.5

a/ Assumes pumps operate 24 hours per day, 365 days per year.
Source: Survey data.

Typical variable expenses per acre-foot, regardless of the source, also differ widely among the four subareas. The highest is Westside at $9 per acre-foot.[1/]

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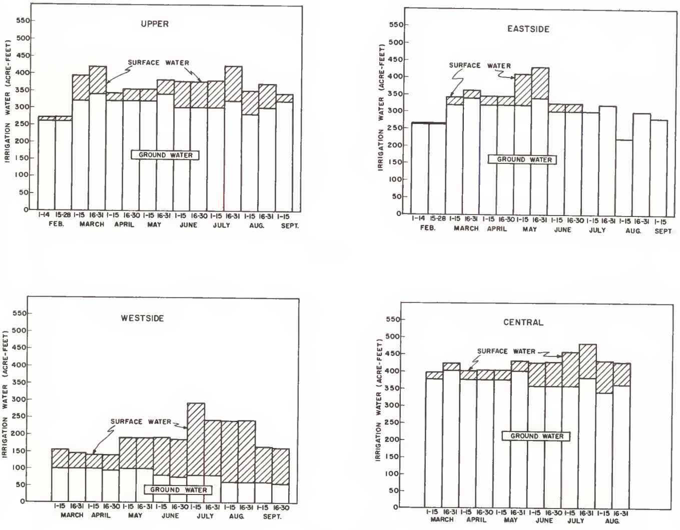
1/ A simple procedure will determine fixed and total costs for irrigation water at the pump head or farm gate, using appropriate estimates for irrigation water variable expenses. Annual fixed or overhead costs for pumping irrigation water under conditions of this study on the 640-acre general crop farms total $13,797 (these costs do not include allowances for farm distribution systems). The rate per acre-foot will vary inversely, according to the quantities pumped; at 3,000 acre-feet, the fixed cost per acre-foot is $4.60; at 2,500, this cost increases to $5.52; at 2,000 acre-feet, it reaches $6.90 per acre-foot and at 1,500, $9.20 per acre-foot. (Continued on page 15.)

FIGURE 3

IRRIGATION WATER SUPPLY FOR FARM MODELS; FOUR SUBAREAS



As the other extreme, Central, with $1.75 per acre-foot, has the lowest water variable cost; Eastside ($3.00) and Upper ($4.50), between the two extremes, are closer to the cost for Central than for Upper.

Real Estate Improvements Reflect Conditions in the Subarea.--All tillable land has been leveled for irrigation, and farm structures are identical for each of the models (see Table 1). Irrigation facilities, however, vary among the subarea models. They are most closely similar in physical characteristics and dollar values for Upper and Eastside with the latter having slightly more feet of underground concrete pipeline. Westside has only one well and pumping plant as compared with five in Upper and Eastside and seven for Central (see Table 1). The model for Central shows more wells and pumping plants (7) but fewer feet of concrete pipeline than any of the other models. Average dollar investments for irrigation facilities vary from $28,000 for Central to $60,000 for Upper and Eastside.

Power and Transport Inventories are Identical for all Four Models.--Each farm unit analyzed in this study is equipped with the same complement of equipment for field power and transportation. This includes one track-layer and five wheel tractors, one ton-and-a-half truck, three pickup trucks, and eight trailers (see Table 1).

Field Machinery Lines are Similar in all Subareas.--The analytical model for Central, with a relatively heavy investment in haying equipment, and the one for Upper, with a slightly greater row crop equipment investment, represent the only variations from a standard pattern of field machinery inventory and investments among the four subareas (see Table 1).

Farm Models Use Both Regular and Seasonal Labor.--That portion of the operator's time not devoted to management supervision, plus three full-time hourly-wage employees (whose perquisites include free housing and utility services), and part-time, hourly-wage workers and seasonally-contracted hand labor as required, constitute the farm labor force for each analytical model. Tasks such as cotton chopping, sugar beet hoeing or thinning, and potato or

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1/(Continued from page 13.) Total water cost per acre-foot equals these fixed costs, plus outlays for irrigation water variable expenses. Thus, at $3.00 per acre-foot for this latter item, total costs under the above range of fixed costs will vary from $7.60 to $12.20 per acre-foot. Similar estimates can be prepared for alternative quantities of water and for other levels of irrigation water variable expenses.

TABLE 1

Farm Real Estate and Operating Equipment Inventories and Investments;
640-Acre Farm Model in Four Subareas

Item	Unit	Upper			Eastside			Westside			Central		
		Quantity	Cost	Average value	Quantity	Cost	Average value	Quantity	Cost	Average value	Quantity	Cost	Average value
1		2	3	4	5	6	7	8	9	10	11	12	13
			dollars			dollars			dollars			dollars	
Land													
Raw land	acre	640	448,000	448,000	640	320,000	320,000	640	409,600	409,600	640	224,000	224,000
Leveling	acre	640	64,000	64,000	640	64,000	64,000	640	64,000	64,000	640	64,000	64,000
TOTAL		640	512,000	512,000	640	384,000	384,000	640	473,600	473,600	640	288,000	288,000
Improvements		8	30,520	15,259	8	30,520	15,259	8	30,520	15,260	8	30,520	15,260
Irrigation													
Pumps	no.	5	23,845	13,187	5	23,845	13,187	1	17,700	9,640	7	18,060	9,849
Wells	no.	5	48,830	24,415	5	48,830	24,415	1	14,000	7,000	7	14,000	7,000
Pipeline	ft.	14,560'	15,141	7,570	17,160'	18,599	9,299	17,160'	18,609	9,299	13,730'	14,880	7,440
Other		889	29,081	15,130	880	26,181	13,430	881	11,104	5,623	703	7,853	3,928
TOTAL			116,897	60,302		117,455	60,331		61,413	31,562		54,793	28,217
ALL REAL ESTATE			659,417	587,561		531,975	459,590		565,533	520,422		341,313	299,477
Power and transportation													
Tractors (TL)	no.	1	17,160	9,781	1	17,160	9,781	1	17,160	9,781	1	17,160	9,781
Tractors (W)	no.	5	15,910	8,909	5	15,910	8,909	5	15,910	8,909	5	15,910	8,909
Trucks	no.	1	3,785	2,081	1	3,785	2,081	1	3,785	2,081	1	3,785	2,081
Pickups	no.	3	7,170	4,660	3	7,170	4,660	3	7,170	4,660	3	7,170	4,660
Trailers	no.	8	4,600	2,250	8	4,600	2,300	8	4,600	2,300	8	4,600	2,300
TOTAL		18	48,625	27,681	18	48,625	27,731	18	48,625	27,731	18	48,625	27,731
Machinery													
Seedbed		11	11,600	5,799	10	11,250	5,624	10	11,250	5,624	10	11,250	5,624
Row crop		6	4,275	2,138	5	3,650	1,826	5	3,650	1,826	5	3,650	1,826
Cotton harv.	no.	1	19,000	10,045	1	19,000	10,045	1	19,000	10,045	1	19,000	10,045
Hay		3	1,340	669	3	1,340	669	3	1,340	669	4	7,340	3,969
Grain		1	800	400	1	800	400	1	800	400	1	800	400
TOTAL		22	37,015	19,051	20	36,040	18,564	20	36,040	18,564	21	42,040	21,864
ALL CHATTELS			85,640	46,732		84,665	46,295		84,665	46,295		90,665	49,595
GRAND TOTALS			745,057	634,293		616,640	505,885		650,198	566,717		463,978	381,072

Source: Calculated by authors from original interview data.

cantaloup harvesting, as well as various nonmechanized production tasks, require hand labor; operators contract this seasonally. Part-time employees serve to supplement the work of the regular year around employees during seasonal work peaks, such as the early summer,when irrigation and cultural requirements are highest for the row crops.

Capital Investments and Annual Fixed Costs Vary Widely.--Total average capital invested in farm real estate and chattels for the four models in this study ranged from about $381,000 in Central to $634,000 in the Upper San Joaquin Valley subareas (see Table 1). Analytical models for Eastside and Westside have total investments of over one-half million dollars. These relatively high average investments involve the usual problems of uncertainty, risk, and the managerial responsibility to obtain returns at least as high from agriculture as can be had from alternative uses for the money. Initial outlays, or original cost, to obtain the resources represented by these investments, were considerably higher than the average values but not as high relatively for the total as for irrigation facilities and farm operating equipment. This is because land and leveling are not depreciated, but are valued at the same level for both original cost and average value.

Variations in total fixed costs among the four farm models closely resemble those in total investments, inasmuch as fixed costs for owning property represent a big proportion of all such costs.[1/] Upper, with $73,170 total, has the highest fixed costs, about $114 per acre. Central ranks the lowest; a $49,030 total for the model in this area represents about $77 per acre.

In this study, we omit fixed costs from the analysis until after determining, through linear programming, the optimum solutions for each of the four models as we vary the independent variables (water prices, annual water quantities, or cotton lint prices). We then consider fixed costs in evaluating total farm returns (including profits) in a later section.

Two elements sometimes included in variable water costs per acre-foot appear under fixed costs in this study -- irrigation demand charges and irrigation district assessments (see Table 2).

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1/ See Appendix Table A-1 for methods of computing fixed costs.

TABLE 2

Summary of Fixed Costs; Four Subareas

Item	Non cash			Cash			Total costs
	Interest	Depreciation	Subtotal	Taxes	Other	Subtotal	
1	2	3	4	5	6	7	8
	dollars						
UPPER							
Land	30,720		30,720	8,960		8,960	39,680
Labor housing	720	900	1,620	294	90	384	2,004
Other improvements	195	295	490	80	20	100	590
Irrigation - original	3,112	5,490	8,602	1,271		1,271	9,873
Irrigation - added	508	968	1,476	207		207	1,683
Power and machinery	2,806	9,501	12,307	1,146	620	1,766	14,073
Social Security; Compensation insurance					1,049	1,049	1,049
Office expense					800	800	800
Irrigation demand charge					1,497	1,497	1,497
Irrigation district assessment					1,920	1,920	1,920
TOTAL	38,061	17,154	55,215	11,958	5,996	17,954	73,169
EASTSIDE							
Land	23,040		23,040	6,240		6,240	29,280
Labor housing	720	900	1,620	270	90	360	1,980
Other improvements	195	295	490	74	20	94	584
Irrigation - original	3,113	5,466	8,579	1,196		1,196	9,775
Irrigation - added	507	968	1,475	194		194	1,669
Power and machinery	2,777	9,404	12,181	1,054	620	1,674	13,855
Social Security; Compensation insurance					1,360	1,360	1,360
Office expense					800	800	800
Irrigation demand charge					1,497	1,497	1,497
Irrigation district assessment					3,200	3,200	3,200
TOTAL	30,352	17,033	47,385	9,028	7,587	16,615	64,000
WESTSIDE							
Land	28,416		28,416	8,288		8,288	36,704
Labor housing	720	900	1,620	294	90	384	2,004
Other improvements	195	289	484	79	20	99	583
Irrigation system	1,893	3,234	5,127	775		775	5,902
Power and machinery	2,777	9,404	12,181	1,134	620	1,754	13,935
Social Security; Compensation insurance					647	647	647
Office expense					800	800	800
Irrigation demand charge					789	789	789
Irrigation district assessment					5,760	5,760	5,760
TOTAL - A a/	34,001	13,827	47,828	10,570	8,726	19,296	67,124
TOTAL - A' b/	34,001	13,827	47,828	10,570	2,966	13,536	61,364
CENTRAL							
Land	17,280	17,280	4,320			4,320	21,600
Labor housing	720	900	1,620	252	90	342	1,962
Other improvements	195	289	484	67	20	87	571
Irrigation system	1,694	2,437	4,131	593		593	4,724
Power and machinery	2,975	9,944	12,919	1,040	645	1,685	14,604
Social Security; Compensation insurance					983	983	983
Office expense					800	800	800
Irrigation demand charge					945	945	945
Irrigation district assessment					2,842	2,842	2,842
TOTAL	22,864	13,570	36,434	6,272	6,325	12,597	49,031

a/ A - Ground-plus-surface water.

b/ A' - Ground-water-only.

Source: Calculated by authors from original interview data.

Our analyses concern initially only those costs that vary as water quantities change during the season; meter charges (or energy), repairs, and other direct pumping costs. Demand charges and irrigation district assessments, once levied, remain the same for a particular production season, regardless of the quantities of water used; hence, they appear under fixed costs in this study.

Crop Yield Estimates Vary According to Irrigation Treatments on Each Soil

An essential step in this analysis was to estimate crop yields for the soils in each subarea, according to specified irrigation treatment practices. These estimates rest on a procedure intended to evaluate how irrigation practices interact with soil-water-plant relationships to regulate yields. Two definitions are important in analyzing relationships, field capacity (FC) and permanent wilting percentage (PWP). The first, FC, represents all the water that a particular soil will hold following a thorough wetting, but after allowing enough time for free water to drain out by gravity. PWP refers to the soil moisture content below which the plants cannot obtain water readily. Plants will wilt at this moisture level, and do not recover unless water is added immediately to the soil.[1/] Questions regarding profitable irrigation practices, therefore, concern the amounts of water to be added, and their proper timing, in order to maintain soil moisture within the range between field capacity and PWP that will enable the operator to maximize net dollar returns.

We base our analysis in this study on the concept that in general the relative rate of plant growth depends upon the mean soil moisture stress in the active root zone; that is, that the tension with which moisture adheres to the soil particles near the active roots regulates the amount of moisture available to the plant and, hence, its growth rate.[2/]

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1/ Viehmeyer, F. J., and A. H. Hendrickson, Essentials of Irrigation and Cultivation of Orchards, Berkeley: University of California, Agr. Ext. Serv. 1950, pp. 4-9 (Circ. 50, Rev. 1950). Viehmeyer, F. J., and A. H. Hendrickson, The Effects of Soil Moisture on Deciduous Fruit Trees, Report of the XIII International Horticultural Congress, 1952, Vol. 1, pp. 306-319. See also: Beringer, Christoph, An Economic Model for Determining the Production Function for Water in Agriculture, Berkeley: University of California Ag. Expt. Sta. Giannini Foundation Research Report No. 240, 1961. This study includes a review of definitions and concepts relating to soil-water-plant relationships appearing in agronomic literature.

2/ Hagan, Robert H., Factors Affecting Soil Moisture-Plant Growth Relations, Report of the XIV International Horticultural Congress, Netherlands, 1955, p. 86; Wadleigh, Cecil H., "Soil Moisture in Relation to Plant Growth," Yearbook of Agriculture, U.S. Department of Agriculture, 1955, Washington 25, D.C., pp. 358-361.

Not all scientists fully accept this view of soil-water-plant relationships. Some researchers of long standing in the field hold that variations in soil moisture content between field capacity and PWP have little bearing on plant development and yield. Some among those who support the mean moisture-stress concept, moreover, concede that brief periods of high stress can have an exaggerated impact upon plant growth. They hold, nonetheless, that the moisture-stress theory represents the best approximation for a wide range of crop under varying soil and climatic conditions.

Yield Estimates Reflect Mean Soil Moisture Availability Ratios

We use the mean soil moisture-availability-stress theory as the basis for analyzing how irrigation affects growth and yields. Irrigation practices through affecting soil moisture stress, therefore represent an important influence regulating profits on the individual farm.1/ We assume in applying this concept that growth is a completely reliable indicator of yield; that any given departure of growth rate from the maximum potential is accompanied by a yield reduction in the same proportion. The starting point for estimating yields associated with each irrigation practice is an estimate of potential yields under optimum soil moisture conditions, obtained from researchers and specialists working on irrigation technology. The subsequent procedure involved six steps for the crops studied on each soil series type, according to a given set of climatic conditions:2/

1. Determining amounts of water, days between each successive pair of irrigations (length of cycle), and timing for applications, under each of three specified irrigation treatments. These represent different percentage depletions of available soil moisture (100, 80, and 60 percents, respectively) permitted before applying water (a combined 80-100 percentage also was used for certain crops).
2. Measuring changes in soil moisture depletion levels throughout each irrigation cycle during the season. We obtained soil moisture release curves representative of each of the soils studied. With these data, we constructed relative growth rate curves, as explained in an earlier report.3/

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1/ Moore, Charles V., "A General Analytical Framework for Estimating the Production Function for Crops Using Irrigation Water," Journal of Farm Economics, Vol. XLIII, Part 1, No. 4, November 1961, pp. 876-888.

2/ See Appendix Figure A-1 and Appendix Tables A-2 and A-3. Also see, Hedges and Moore, Economics of On-Farm . . . . 1. Enterprise Choices, Resource . . ., pp. 25-36, (includes a more complete discussion of this procedure).

3/ Ibid., pp. 25-32.

3. Estimating plant growth (hence yields) according to levels of available soil moisture for each irrigation cycle. Relative growth curves provide the basis for these estimates.

4. Establishing the mean growth rates for each crop during each cycle according to soils and irrigation treatments, and expressing each as an index of the potential yield possible under physically optimum moisture conditions.

5. Cumulating the growth rates (and yields) for the several cycles into a seasonal yield index for each crop, according to soils and irrigation treatments.

6. Applying the seasonal yield indices from (5) to the potential yields estimated to obtain yields associated with each of the various irrigation treatments for crops involved on each soil series type.

Our approach uses the 100 percent level (dry), plus the 80 and 60 percent levels (medium, and wet), respectively, to define the three major irrigation practices for analysis. A fourth practice, used for some crops, is the 80-100 percent level (mixed), in which the 80 percent level applies to the early portion, and the 100 percent level to the latter portion of the season. Thus, this analysis may include as many as four soil-crop-irrigation practice combinations for a particular crop on a single soil, although usually a fewer number appears.

NATURAL, ECONOMIC, AND INSTITUTIONAL FACTORS GOVERN COMPETITION AMONG SUBAREAS

Each San Joaquin Valley Cotton Subarea Includes Some Excellent Soils

Grades I and II soils, according to the Storie Index, account for about one-half of all crop land acreage in the Upper San Joaquin Valley and on the Eastside, for approximately 60 percent on the Westside, for only about 21 percent in the Central San Joaquin Valley (see Table 3). This evaluation, based on available soil survey reports for much of the total area (data for Central include only Madera County), indicates that soils are highly productive for irrigated agriculture in most of the San Joaquin Valley cotton-growing area. Total acreages classed as Grade I or II range from 530,000 on the Eastside to nearly 600,000 on the Westside in the three main cotton subareas, but account for only 183,000 acres in Central.

Grade III soils also represent an important percentage of all land resources in each of the four subareas, Upper San Joaquin Valley, with 23 percent of the total in this grade, having the largest percentage (see Table 3).

Table 3

Soil Resources by Grades; Four Subareas in the San Joaquin Valley[a]

Storie Soil classification		Upper		Eastside		Westside		Central	
Grade	Index	Acres	Percent of total	Acres	Percent of total	Acres	Percent of total	Acres	Percent of total
1	2	3	4	5	6	7	8	9	10
I	80-100	276,608	22.0	291,584	26.1	418,225	46.4	105,175	12.1
II	60- 79	307,648	24.4	238,144	21.3	132,200	14.6	78,171	9.0
III	40- 59	285,248	22.6	178,496	15.5	109,950	12.2	153,814	17.7
IV	20- 39	126,720	10.1	144,192	13.4	119,350	13.2	301,315	34.7
V and below	10- 19	263,296	20.9	265,664	23.7	122,675	13.6	228,871	26.3
TOTALS		1,259,520	100.0	1,118,080	100.0	902,400	100.0	867,346	100.0

a/ Calculated by authors from data listed in Soil Survey reports:

Upper; Bakersfield and Wasco
Eastside; Fresno, Hanford, Pixley, and Visalia
Westside; Western Fresno County
Central; Madera County

These soils data give a reasonably definite indication of the relative production potential for intensive (thus irrigated) crops in the four subareas. Soils in the Grades I and II classifications account for most of the high gross-value-per-acre production throughout the cotton-growing area, with Grades III and IV soils usually finding their most economic use in grains and irrigated pasture. Thus, Westside has the highest production potential, Upper and Eastside rank about equally in second place, and Central is at the lowest level, according to soil quality alone.

Soil data cited above are aggregates for the entire area included in each of the soil survey reports. Distribution according to soil quality for individual farms, therefore, will not necessarily agree fully with this information. Nevertheless, they do correspond reasonably well, except for Central. This is because in most of the cotton-growing valley, each soil quality tends to occur in sizable blocks, Central again being the exception. In Madera County, cited here to represent soils conditions in the Central San Joaquin Valley, the various soil bodies are much more dispersed and intermingled than is true for the other three subareas.

Climatic Characteristics Affect Crop Adaption and Yields

Climate is an important influence regulating the economic adaptation and profitability of crops, and particularly of cotton which is highly important in all four of the southern San Joaquin Valley subareas. Doyle has pointed out that about 77.0°F. appears to be the average summer temperature below which commercial cotton production becomes unprofitable, and that such temperatures characterize the northern boundary of the Cotton Belt in the United States.[1/] Variations in summer temperatures represent the principal climatic difference among the four San Joaquin Valley cotton-growing subareas. They feature in common relatively mild winters, low annual precipitation with rainless summers, and long growing seasons, the latter varying in length from 242 days for Westside to 269 days for Eastside. This latter subarea also has summer mean temperatures (June, July, and August) that average 77.4°F (see Figure 4). Averages range from about one to nearly five degrees higher for these months in Upper and Westside

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1/ Doyle, C. D., "Climate and Cotton", U.S. Department of Agriculture Yearbook 1941, U.S. Government Printing Office, Washington, D.C., p. 362.

subareas, and also are higher during the spring and fall months. In contrast, temperatures in Central are lower than in Eastside during the entire cotton-growing season from April through October, and range from one to two degrees lower during June, July, and August (see Figure 4). These data, like those for soils, indicate that the Central San Joaquin Valley subarea is at some disadvantage compared with the other three in cotton production. Irrigation is essential for commercial cotton growing, as for all other summer crops in each of the four subareas. Thus variations in water availability and/or cost among these subareas also may generate differences among crops in adaptability for economic production and, therefore, in relative profit rankings.

Cotton-Producing Subareas Vary Widely in Irrigation Water Availability and Cost

Most summer-growing crops, throughout the cotton-producing portion of the San Joaquin Valley, obtain only a relatively small proportion of total water requirements for economic yields directly from precipitation; most water used (all of it during the summer months) is supplied by irrigation. At the time of this study, ground water represented an important fraction of all irrigation water throughout the four subareas. Its relative importance in total farm quantities available varied from 100 percent for Westside to 87 percent for Central. But depth to water, total pumping lift, size of motor and energy requirements, and other pumping characteristics vary widely among these areas (see Figure 1). Pumping costs, both fixed costs and variable expenses, also differ as does the total annual quantity of water available, and its seasonal distribution.[1/] Quality, too, often is a factor; for example ground water in Westside where relatively high mineral content shortens pumping plant life and thus increases fixed and total costs.

Limited quantities of water available for irrigation use present a problem of greater or lesser degree in all four subareas, probably least in relationship to acreages of high quality land for Central. Westside is the subarea

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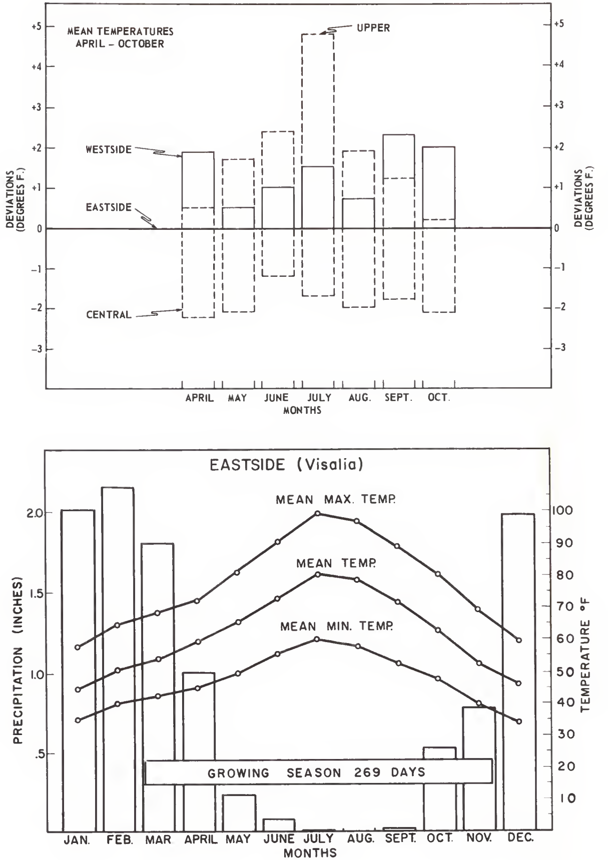
1/ See Hedges, Trimble R., and Charles V. Moore, "Irrigation Pumping Plant Characteristics in the San Joaquin Valley," California Agriculture, Vol. 14. No. 8, August 1960, pp. 2-3; and Moore, Charles V., and Trimble R. Hedges, "Irrigation Costs of Pumping in the San Joaquin Valley," California Agriculture, Vol. 14, No. 10, October 1960, pp. 3-4.

FIGURE 4.
Mean Temperature Deviations in Upper, Westside, and Central
Subareas from Eastside; Precipitation and Growing Season in Eastside



with the most serious water shortage problem; the continually dropping water tables over a period of years, in the absence of effective recharge, has resulted quite generally in extremely high pumping costs (total costs commonly equal or exceed $25 per acre-foot).

Water sources, facilities, and costs used in analyzing the four subarea models reflect existing conditions, except for Westside. Two considerations led us to use a different approach in specifying irrigation water conditions and costs for Westside: First is the point mentioned above; the present critical underground water situation plus its continuing deterioration; second, California Water Plan developments indicate that surface water will be available to the Westside subarea through the San Luis project within the not too distant future. Our analysis, therefore, recognizes these factors, and considers their possible effects in a 640-acre model on Westside with sizable amounts of surface water available. Actually, except under such conditions, a 640-acre model has no realism for Westside. Few such units exist there now, and the relatively high cost of developing wells and obtaining water make it highly unlikely that their number will expand unless and until surface water is available at prices considerably below present costs for providing underground water.1/

Economic Variations among Subareas are Important

Cotton Ranks First among Field Crops.--Cotton is the highest ranking crop according to net returns-over-variable expenses (fixed costs not considered) per acre in all four subareas under conditions of this study (based on the period 1956-1960). Important variations among subareas appear, however, in adapted crops, absolute net returns levels, and relative ranking among crops (see Figure 5). This analysis includes, in addition to cotton, alfalfa hay, Blackeye beans, milo (single- and double-cropped with barley), and barley in all subareas. Irish potatoes appear in the ranking for Upper, melons for Eastside and Westside, and

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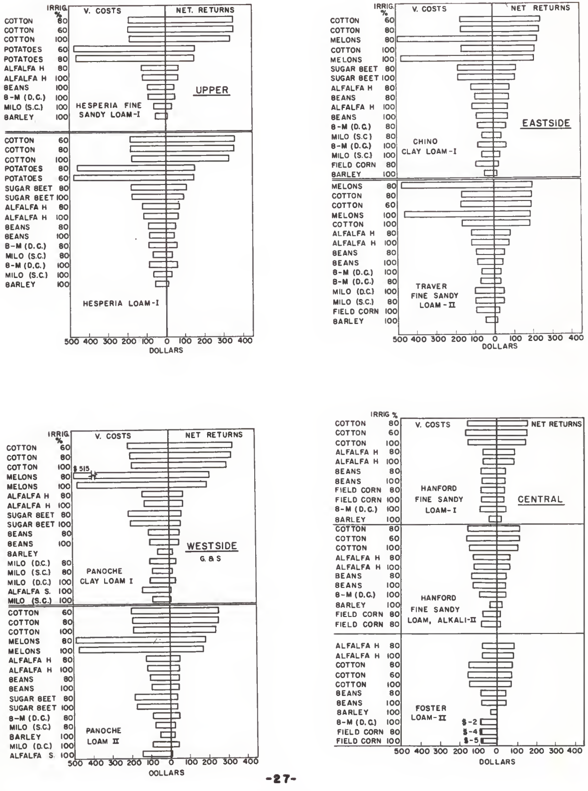
1/ Corporate ownership exists throughout the cotton-growing area of the San Joaquin Valley. It dominates in Westside, where much of the land, originally acquired under Railroad Acts, is still held by railway companies, and considerable additional acreage is owned by large oil corporations (corporations also control sizable acreages of cultivated land in Upper, and are important in both the other two subareas, particularly in certain localities).

FIGURE 5

NET RETURNS PER ACRE FOR SPECIFIED CROPS, BY SOILS AND IRRIGATION TREATMENTS; FOUR SUBAREAS



field corn for Central. Net returns data for some of the crops in the several subareas appear in the Appendix, though not shown in Figure 5.[1/]

Crop rankings according to net returns-over-variable expenses per acre reflect the soil-crop-irrigation treatment combinations; thus, one crop may appear as an income activity two or more times in these rankings (see Figure 5).[2/] Typically, corporations that own sizable acreages of land suitable for cultivation in the Westside lease this land to farmers, individual or corporate operators, usually under a developmental lease providing for the operator to provide the capital required in leveling, making water available, and providing farm water distributing facilities.

The relatively high proportion of corporate ownership, plus water shortages and high water costs, in Westside have combined to encourage relatively large-scale operations in this area. Thus, in 1954 Fresno County Agricultural Stabilization and Conservation Committee records showed only 154 contracts in western Fresno County with 575,080 crop acres. In comparison, eastern Fresno County listed 4,180 contracts with 394,800 acres of crop land during 1954. Considering all counties in each subarea, in 1954 the ASC records showed 9,570 contracts and 1 million acres of crop land on the Eastside, as compared with 304 contracts and 1.25 million acres of crop land on the entire Westside. Western Fresno included 154 of these latter operations with 575,000 crop acres. Upper San Joaquin Valley had 1,780 contracts and 390,300 acres in crop land, and Central, 1,690 contracts with 290,000 acres of crop land.

We evaluated all field crops in each subarea that farmers commonly grow on any substantial acreage. Melons, appearing here in the rankings for Eastside and Westside, in these analyses represent specialty crops in general. A wide variety of such crops collectively account for a sizable acreage in all subareas except Central, but no one crop dominates this specialty crop group, except for potatoes in Upper and cantaloups on the Westside. We chose melons to represent the specialty crops in Eastside, as well as Westside, for convenience in analysis; we do not suggest that this crop necessarily has an earnings advantage over other possible choices available to any particular individual operator.

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1/ See Appendix Table A-5.
2/ This is one reason for referring to a particular soil-crop-irrigation practice combination as an "activity" in linear programming procedures and solutions.

The ranking order according to net returns per acre for crops in the Upper San Joaquin Valley is as follows: cotton, potatoes, sugar beets, alfalfa hay, beans, milo (double- and single-cropped with barley), and barley (see Figure 5). In this ranking all soil-crop-irrigation practice combinations for each crop rank above all those for the next lower ranking crop. Some overlappings are evident, however, in comparing the several combinations for each individual crop.

Crop rankings according to net returns for Eastside and Westside agree in general with those for Upper, except that alfalfa hay ranks higher than sugar beets on the Westside. In Eastside and Westside, cotton ranks first, with melons (the specialty crop representative) second, and the other crops following in order.

Central differs sharply from the other three subareas in that the ranking includes no specialty crop, sugar beets do not appear, and field corn appears in the ranking according to net returns-over-variable expenses.

Grains, as a group, rank lowest in all four subareas, but the relative positions of the individual crops varies considerably. Double-cropped milo occupies first place among the grains group, and immediately after Blackeye beans, on all soils in all subareas, except Grade I soil in Westside and Grades I and III soils in Central (see Figure 3). Net returns for this crop range from as high as $43 per acre in Eastside to as low as $12 per acre in Westside.

Barley is at the bottom of the list on both soils in Upper and Eastside, but on Westside ranks above all other grains on the Grade I soils, and above double-cropped milo. The barley ranking on net returns differs among soils in Central; it is lowest on Grade I, ahead of field corn on Grade II, and above both this crop and double-cropped milo on Grade III soils. Milo is more profitable than field corn in both Eastside and Central, the only two subareas for which field corn was tested. Returns from beans in Eastside are $74-$81 per acre, or about $25 higher than earnings for this crop in the other three subareas.

Several conclusions follow from these net returns rankings on crops in the several subareas. Cotton clearly is the most profitable field crop commonly grown throughout the entire study area. Specialty crops, however, offer the closest earning-per-acre competition to cotton in the three subareas where natural resource conditions, available markets, managerial "know-how," adequate supplies of available capital, and other determining factors favor their production. Alfalfa hay (the crop occupying the largest acreage in the study area)

and sugar beets, occupy a middle position in the rankings according to net returns for three areas. Blackeye beans and milo (typically double-cropped milo) come next in the profit rankings with the beans offering somewhat the higher net returns. Barley (or single-cropped milo) is at the lowest level in the rankings.

Cotton, the highest net returns crop, shows the widest variations in net returns-over-variable expenses (other than water costs) per acre among the four subareas; maximum values by subareas were Upper \$358, Westside \$331, Eastside \$249, and Central \$158 per acre, respectively. Relative yields are important in explaining these net returns differentials; soil and climatic differences largely explain the yield variations. The county average five-year (1956-1960) cotton lint yield per acre in the study area was, by counties, Kern 1,128 pounds, Fresno 1,075 pounds, Tulare 893 pounds, and Madera 806 pounds. This comparison understates the Westside yield, inasmuch as it includes cotton grown in the portion of Fresno County that is included in the Eastside. Yields in this portion of the county are lower than those in Westside. As for specialty crops, little difference exists for melons as between Eastside and Westside, but both these subareas show higher returns for melons than Upper receives from potatoes. Earnings from sugar beets, in contrast, are comparable in Upper and Eastside, and are distinctly higher in both subareas than in Westside.

Farm Size Distribution Varies Sharply among Subareas.--An earlier report determined that farm size sharply influences how water prices and/or annual quantities available affects the economics of using irrigation water to grow cotton and other general field crops.[1/] Farm size distributions vary markedly among the four subareas studied. This size factor, therefore, operates differently among the several subareas. Data in the following text table, based on 1954 California Agricultural Stabilization and Conservation Committee records in the San Joaquin Valley, indicate the extent and degree of farm size variation in farm operations with cotton allotments during that year.

Under conditions existing in 1954, and during the period covered by this study, farms of 421 acres or larger represent by far the greatest proportion of

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1/ Moore and Hedges, Economics of On-Farm . . . . 2. Farm Size in Relation to . . . .

Acres	Number of Farms by Acres of Crop Land								
	Upper	Eastside			Westside		Central		
	Kern	East Fresno	Kings	Tulare	West Fresno	Other	Madera	Merced	Total
1- 20	369	347	226	402	245	194	--	--	1,783
21- 60	1,772	1,296	394	376	184	114	24	20	4,180
61- 100	344	461	207	238	108	77	--	--	1,435
101- 220	1,308	1,048	518	554	301	187	24	12	3,952
TOTAL	3,424	2,805	1,119	1,168	593	378	48	32	9,567
221- 420	1	2	--	12	9	38	27	65	154
421-1,100	--	--	--	--	--	--	78	72	150
TOTAL	1	2	--	12	9	38	105	137	304
1,101-2,000	248	394	190	200	98	60	27	--	1,217
2,001-over	62	97	81	107	58	64	--	--	469
TOTAL	310	491	271	307	156	124	27	--	1,686

all cotton-producing farms on the Westside, with Upper San Joaquin Valley ranking next in the proportion of all farms in relatively large sizes. Small operating units definitely dominate in Eastside and are quite important in Central. Farm units with fewer than 1,100 acres of crop land are relatively unimportant, in terms of either number or acres of crop land on the Westside.

Upper and Westside Have Well-Developed Specialty Crop Marketing Facilities.--Potatoes are a well-established and commonly grown specialty crop in Kern County. Well-located and efficient potato packing sheds are readily available; larger operators own and operate their own facilities, while the smaller ones contract with shed operators for the packing services necessary in potato marketing. Comparable facilities are available for cantaloups on the Westside. Quite commonly in this subarea a single farm producer, or a relatively small group of producers, will own and operate a shed. Custom melon packing is available, however, for those whose operations do not justify owning a packing shed.

Packing facilities for these two crops, and certain others such as green-wrapped tomatoes, sweet corn, lettuce, and dry onions, are scattered throughout the cotton-producing area of the San Joaquin Valley. Fruit packing and processing establishments, of course, also are available, primarily in Eastside and Central, but to some extent in Upper.

Specialty crops quite commonly require special marketing arrangements, such as contracts, in addition to special facilities. Growers in Upper (for potatoes) and Westside (for cantaloups) have a distinct advantage over those in the other two subareas because market outlets and packing facilities are already established and regularly handle substantial volumes of these products each year.

Marketing outlets and facilities for cotton, alfalfa hay, Blackeye beans, and the feed grains are available throughout the four subareas. Farmers who wish to grow sugar beets also should have little difficulty in arranging market outlets, providing they are able to obtain "proportionate shares" during years when acreage restrictions are enforced. One of the major sugar companies recently built a sugar factory on the Westside.

WATER PRICE LEVELS AT WHICH TOTAL FARM NET RETURNS EQUAL ALL FIXED COSTS DIFFER SHARPLY AMONG SUBAREAS

Total Farm Net Returns Decline as Water Prices Rise

Optimum solutions, as determined by linear programming for each farming system within each of the four subareas, cover a wide range, as water prices

(variable expenses) vary from zero to $32 per acre-foot (see Figure 6). These solutions represent total farm net returns-over-variable expenses at different variable costs for water. They afford an effective comparison among farming systems in a particular subarea and among subareas as to the degree that changes in water prices affect farm returns. These total farm net returns data, evaluated vis-à-vis total farm fixed costs, also provide useful indications of overall farm performance.

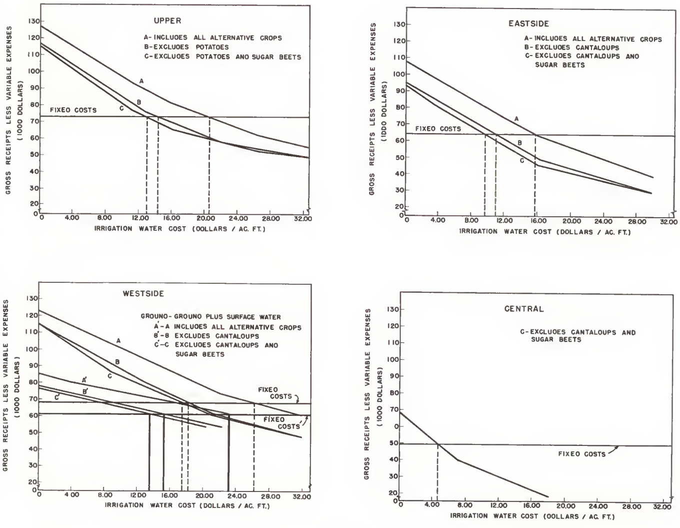
A farmer seeks revenue above that required to cover variable expenses and fixed costs (cash fixed costs, depreciation, and interest on his capital investments). He also wants a dollar reward for management, supervision, and risking his capital. He receives nothing for these services at water prices (variable expenses) associated with total farm net returns-over-variable expenses exactly equal to fixed costs; he sustains losses if net returns drop below fixed costs. A later section presents data on profits and other conventional farm earnings measures, and examines these concepts and their application to this study in somewhat greater detail.

Data for cropping System C (excluding cantaloups, or potatoes, and sugar beets) indicate important differences among subareas in the water prices at which net returns-over-variable expenses exactly break even with total farm fixed costs ("break-even prices") (see Figure 6). The range is from $4.75 per acre-foot for Central to $17.50 for the ground-plus-surface water combination in Westside. The break-even price for ground water-only in Westside ($14.00) and Upper ($13.00) differ by only $1.00; Eastside's $10.00 break-even price is much closer to these two than the $4.75 figure for Central.

This analysis establishes clearly that important earnings differences exist among the 640-acre analytical models in the four subareas. Operators on cotton-general crop farms (with no specialty crops) in Westside and Upper are able to obtain total farm net returns equivalent to all fixed costs at higher water prices per acre-foot than growers in either Eastside or Central. Some caution is necessary in comparing Upper and Westside according to these data. Data for the latter subarea are more subject to error than those for any of the other three. This is because it was necessary to specify characteristics for the farm model in this subarea by synthesis, without the advantage of local farm organization data.

FIGURE 6

FARM NET RETURNS AND IRRIGATION WATER VARIABLE COSTS; FOUR SUBAREAS



The three subareas in which specialty crops are sufficiently important to justify analyzing all three farming systems (A, B, and C) show break-even water prices at decidedly higher price levels for System A, and somewhat higher levels for System B than for System C (see Figure 6 and Table 4). In Upper, for example, the break-even price for a farming system that includes potatoes and sugar beets, as well as cotton and the other general crops, is about $20.75 -- almost $8.00 per acre-foot above the break-even price for System C. The B System, excluding potatoes, shows a break-even price of about $14.25, as compared with $13.00 for the farm with System C crops. Two points are evident; first, farmers who presently are in position to grow and market specialty crops successfully can operate at higher water prices than those who are not; second, further increases in opportunities for producing and marketing these crops may both extend the advantage of farmers already growing them, and add other farmers to their number.

Subareas Vary Widely in Maximum Net Returns and Quantities of Water Used

We also used linear programming to determine optimum solutions according to water use as quantities vary from zero to the limit of farm supply for each model, or until added quantities bring no further increases in total farm net returns. Prices (variable expenses) per acre-foot, remaining unchanged throughout the entire range of quantities for each farm model, are as follows: Upper $4.50, Eastside $3.00, Westside $9.50, and Central $1.75.[1/] These variable costs apply to water regardless of whether it comes from underground or surface sources. Considering only farming System C, Upper, with approximately $100,000 total for net farm returns-over-variable expenses at 3,463 acre-feet of water used, is at one extreme, and Central, with $62,660 in net returns at 3,490 acre-feet of water used, at the other (see Figure 7 and Table 5). The analytical model for Westside (ground-plus-surface water) has the lowest total water use (2,520 acre-feet) but, with $90,170 net returns, exceeds Eastside in earnings despite the fact that the Eastside farm's total water use of 2,760 acre-feet is higher.

The Westside farm with both ground and surface water uses much larger quantities of water and shows sharply higher total farm net returns at maximum

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1/ These particular prices reflect typical costs in the respective subareas during the study period.

TABLE 4

Variations in Farm Net Returns-Over-Variable Costs, and Irrigation Water Variable Costs; Four Subareas

Net returns	Price per acre-foot	Quantity	Net returns	Price per acre-foot	Quantity	Net returns	Price per acre-foot	Quantity
1	2	3	4	5	6	7	8	9
dollars		acre-feet	dollars		acre-feet	dollars		acre-feet
A. Includes all alternative crops			B. Excludes potatoes			C. Excludes potatoes and sugar beets		
Upper San Joaquin Valley								
126,565	0.00	3,165	117,314	0.00	3,356	115,457	0.00	3,463
112,645	4.44	3,153	87,534	8.87	3,200	84,731	8.87	3,278
109,577	5.40	2,985	86,266	9.27	2,794	83,431	9.27	2,738
106,776	6.31	2,842	80,554	11.31	2,621	77,835	11.31	2,676
92,658	11.28	2,332	76,363	12.91	2,591	73,555	12.91	2,637
81,225	16.18	2,035	69,190	15.68	2,049	66,255	15.68	2,113
69,642	21.88	1,595	68,168	16.76	1,601	65,205	16.18	1,219
66,507	23.88	1,434	59,054	21.88	1,162	58,262	21.87	892
63,054	26.24	1,322	56,771	22.63	1,000	54,659	25.91	887
62,755	26.47	1,277	54,362	26.24	888	54,161	26.47	844
55,200	32.40	1,207	49,171	32.39	773	49,171	32.40	773
A. Includes all alternative crops			B. Excludes cantaloups			C. Excludes cantaloups and sugar beets		
San Joaquin Valley Eastside								
108,403	0.00	3,050	95,205	0.00	3,232	92,076	0.00	3,065
98,134	3.36	3,007	86,215	2.76	3,205	84,793	2.40	2,837
96,238	3.96	2,807	84,320	3.36	2,727	83,627	2.76	2,833
75,105	11.52	2,650	61,630	11.64	2,689	81,972	3.36	2,762
74,009	11.88	2,457	50,004	15.96	2,374	47,061	15.96	2,746
63,425	16.20	1,951	49,452	16.20	1,628	46,421	16.20	1,616
61,768	17.04	1,926	48,068	17.04	1,626	46,205	16.32	1,241
59,617	18.24	1,502	46,253	18.24	1,566	29,515	29.88	1,198
53,666	22.08	1,443	35,003	25.44	1,241	--	--	--
42,558	29.88	1,408	29,515	29.88	1,198	--	--	--
San Joaquin Valley Westside (ground-plus-surface water)								
123,330	0.00	2,418	115,884	0.00	2,784	110,888	0.00	2,653
118,733	1.90	2,403	106,075	3.57	2,759	110,841	1.74	2,599
118,001	2.21	2,346	103,213	4.56	2,737	103,169	2.95	2,467
106,064	7.29	2,295	97,671	6.59	2,702	102,489	3.23	2,354
105,857	7.38	2,291	88,350	10.04	2,620	91,225	8.01	2,335
104,353	8.04	2,263	86,902	10.59	2,554	87,015	9.82	2,287
102,259	9.00	2,193	85,345	11.20	2,488	77,496	13.98	2,244
97,441	11.19	2,184	82,003	12.54	2,466	71,722	16.56	1,985
96,259	11.73	2,172	81,527	12.73	2,388	62,087	21.41	1,748
90,803	14.24	2,136	77,421	14.46	2,328	61,008	22.03	1,639
88,066	15.53	2,044	74,642	15.65	2,309	60,158	22.55	1,606
87,357	15.89	1,943	72,621	16.52	2,267	57,976	23.90	1,158
84,363	17.44	1,940	69,978	17.70	2,233	48,371	32.20	1,120
79,415	19.98	1,807	67,722	18.71	2,215			
78,642	20.41	1,579	66,037	19.46	2,128			
75,640	22.31	1,435	65,485	19.73	2,013			
73,357	23.90	1,406	62,099	21.41	1,799			
61,686	32.20	1,369	61,009	22.03	1,639			
			57,976	23.90	1,158			
			48,371	32.20	1,120			
San Joaquin Valley Westside (ground-water-only)								
85,311	0.00	1,070	77,825	0.00	1,091	76,537	0.00	1,036
80,810	4.21	1,052	54,473	21.41	938	75,227	1.26	1,033
76,691	8.12	1,037	53,623	22.32	880	54,420	21.41	880
67,994	16.51	1,028						
61,609	22.72	1,024						
Central San Joaquin Valley								
						68,583	0.00	3,491
						65,277	.95	3,269
						40,638	7.21	3,056
						37,990	9.35	2,593
						27,189	13.51	2,304
						21,893	15.82	1,751
						18,639	17.67	1,355
						18,593	17.71	1,177
						18,327	17.93	1,009
						18,263	18.00	730

Source: Calculated by authors.

TABLE 5

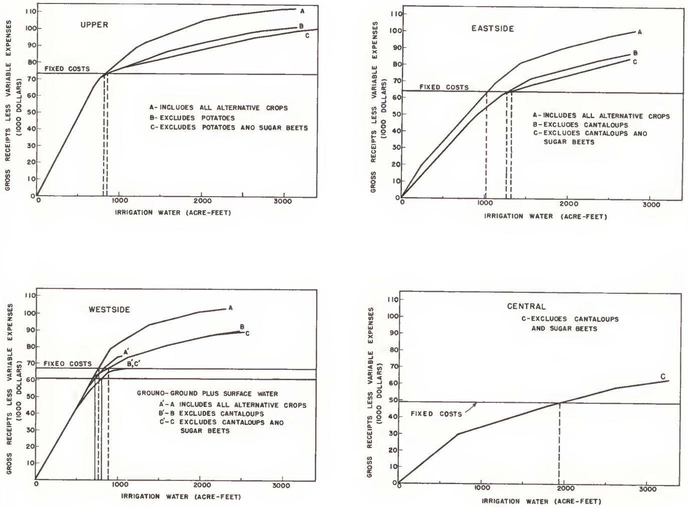
Variations in Farm Net Returns-Over-Variable Costs at Varying Quantities of Irrigation Water; Four Subareas

Net returns		Irrigation water		Net returns per acre-foot	Net returns		Irrigation water		Net returns per acre-foot	Net returns		Irrigation water		Net returns per acre-foot
Totals	Changes	Totals	Changes		Totals	Changes	Totals	Changes		Totals	Changes	Totals	Changes	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
dollars		acre-feet		dollars	dollars		acre-feet		dollars	dollars		acre-feet		dollars
A. Includes all alternative crops					B. Excludes potatoes					C. Excludes potatoes and sugar beets				
Upper San Joaquin Valley														
0	0	0	0	.00	0	0	0	0	.00	0	0	0	0	.00
65,488	65,488	676	676	96.88	65,488	65,488	676	676	96.88	65,488	65,488	676	676	96.88
70,738	5,250	773	97	54.12	70,738	5,250	773	97	54.12	70,738	5,250	773	97	54.12
88,859	18,121	1,207	434	41.75	72,694	1,956	844	71	27.55	72,694	1,956	893	70	27.94
90,815	1,956	1,277	70	27.94	73,672	978	888	44	22.23	73,672	978	888	45	21.73
91,793	978	1,322	45	21.73	76,105	2,433	1,000	112	21.72	73,755	83	892	4	20.75
94,227	2,434	1,433	111	21.93	79,230	3,125	1,162	162	19.29	79,437	5,682	1,219	327	17.38
97,351	3,124	1,595	162	19.28	86,870	7,640	1,601	439	17.40	89,511	10,074	2,113	894	11.27
104,991	7,640	2,035	440	17.36	91,915	5,045	2,059	458	11.02	95,133	5,622	2,637	524	10.73
108,336	3,345	2,332	297	11.26	97,733	5,818	2,591	532	10.94	95,467	334	2,679	42	7.95
111,398	3,062	2,842	510	6.00	97,987	254	2,621	30	8.47	96,470	1,003	2,836	157	6.39
112,175	777	2,985	143	5.43	98,692	705	2,733	112	6.29	98,413	1,943	3,156	320	6.07
112,320	145	3,153	168	.86	101,244	2,552	3,154	421	6.06	99,869	1,456	3,463	307	4.74
					102,207	963	3,356	202	4.77					
A. Includes all alternative crops					B. Excludes cantaloups					C. Excludes cantaloups and sugar beets				
San Joaquin Valley Eastside														
0	0	0	0	.00	0	0	0	0	.00	0	0	0	0	.00
19,060	19,060	229	229	83.23	43,995	43,995	780	780	56.40	43,995	43,995	780	780	56.40
63,056	43,996	1,009	780	56.41	49,861	5,866	895	115	51.01	49,861	5,866	895	115	51.01
68,922	5,866	1,125	116	50.57	62,581	12,720	1,198	303	41.98	62,581	12,720	1,198	303	41.98
70,681	1,759	1,160	35	50.26	63,842	1,261	1,240	42	30.02	63,843	1,262	1,240	42	30.02
81,096	10,415	1,408	248	41.99	72,038	8,196	1,563	323	25.37	68,867	5,025	1,616	376	13.36
82,128	1,032	1,443	35	29.49	73,093	1,055	1,626	63	16.75	83,953	15,086	2,746	1,130	13.35
83,546	1,418	1,517	74	19.16	83,082	9,989	2,374	748	13.35	84,152	199	2,762	16	12.44
90,448	6,902	1,926	409	16.87	87,134	4,052	2,689	315	13.34					
90,787	339	1,950	24	14.12	87,489	355	2,735	46	7.72					
97,550	6,736	2,457	507	13.34										
99,312	1,762	2,650	193	9.13										
100,641	1,329	2,807	157	8.46										
San Joaquin Valley Westside (ground-plus-surface water)														
0	0	0	0	.00	0	0	0	0	.00	0	0	0	0	.00
60,930	60,930	690	690	88.30	60,930	60,930	690	690	88.30	60,930	60,930	690	690	88.30
78,663	17,733	906	216	82.10	65,394	4,464	809	119	37.51	65,394	4,464	809	119	37.51
80,228	1,565	939	33	47.42	73,829	8,435	1,120	311	27.12	73,829	8,435	1,120	311	27.12
84,692	4,464	1,058	119	37.51	74,671	842	1,158	38	22.16	74,671	842	1,158	38	22.16
93,127	8,435	1,369	311	27.12	80,857	6,186	1,597	439	14.09	80,857	6,186	1,597	439	14.09
94,041	914	1,412	43	21.25	81,290	433	1,629	32	13.53	81,290	433	1,629	32	13.53
101,082	7,041	1,978	566	12.44	83,759	2,469	1,832	203	12.16	83,759	2,469	1,832	203	12.16
101,779	697	2,037	59	11.81	86,151	2,392	2,033	201	11.90	86,151	2,392	2,033	201	11.90
102,330	551	2,101	64	8.61	86,481	330	2,061	28	11.78	86,715	564	2,086	53	10.64
102,906	576	2,175	74	7.78	87,227	746	2,131	70	10.66	87,533	818	2,164	78	10.49
103,168	262	2,209	34	7.70	87,987	760	2,211	80	9.50	88,470	937	2,273	109	8.60
103,290	122	2,228	19	6.42	89,225	1,238	2,364	153	8.09	89,225	755	2,364	91	8.30
103,383	93	2,310	82	1.13	89,932	707	2,458	94	7.52	89,689	464	2,424	60	7.73
					90,186	254	2,508	50	5.08	90,067	378	2,480	56	6.75
					90,299	113	2,603	95	1.19	90,172	105	2,518	38	2.76
San Joaquin Valley Westside (ground-water-only)														
0	0	0	0	.00	0	0	0	0	.00	0	0	0	0	.00
40,496	40,496	459	459	88.23	40,496	40,496	459	459	88.23	40,496	40,496	459	459	88.23
54,993	14,497	635	176	82.37	53,717	13,321	662	203	65.62	53,717	13,221	662	203	65.13
57,709	2,716	676	41	66.24	64,805	11,088	878	216	51.33	64,805	11,088	878	216	51.33
59,118	1,409	699	23	61.26	65,609	804	937	59	13.63	66,695	1,890	1,036	158	11.96
66,677	7,559	821	122	61.96	67,438	1,829	1,091	154	11.88					
67,731	1,054	843	22	47.91										
69,693	1,962	889	46	42.65										
73,884	4,191	988	99	42.33										
74,562	678	1,038	50	13.56										
Central San Joaquin Valley														
										0	0	0	0	.00
										30,158	30,158	730	730	41.31
										34,296	4,138	985	255	16.23
										37,416	3,120	1,179	194	16.08
										46,517	9,101	1,751	572	15.91
										54,301	7,784	2,304	553	14.08
										57,696	3,395	2,593	289	11.75
										61,213	3,517	3,056	463	7.60
										62,647	1,434	3,269	213	6.73
										62,655	8	3,491	222	.04

Source: Calculated by authors.

FIGURE 7

FARM NET RETURNS AT VARYING QUANTITIES OF IRRIGATION WATER; FOUR SUBAREAS



water use than the comparison unit for Westside with only ground water (see Figure 7 -- Westside).

Again, in this analysis when water quantities vary with prices constant, analytical models including specialty crops as alternatives (Systems A and B) show distinctly higher earning capacity. Farming System A (including potatoes for Upper and cantaloups for Eastside and Westside) ranks the highest for all three models that include specialty crops (see Figure 7). The B System shows little advantage over C in total farm net returns for Westside, but is definitely higher in net returns for comparable water quantities in Upper and Eastside.

Break-even points for the System C model occur at much smaller water quantities in Upper and Westside than for the other two subareas, at 850-875 acre-feet as compared with 1,300 in Eastside and 1,950 in Central. Farming systems in these higher return subareas that include specialty crops among the alternatives show break-even points at still lower quantities of irrigation water for System A at 760 acre-feet in Westside, 825 in Upper, and 1,025 in Eastside (see Figure 7 and Table 5).

Net returns per added foot of irrigation water are highest for the early water increments, but decline sharply with successive additions in all subareas and for all three farming systems (see Table 5). Here again, net returns per acre-foot for System C are highest in Upper with Westside ranking next; Eastside follows at a sharply lower level, and Central is at the bottom of the ranking.

ADJUSTMENTS TO CHANGING WATER CONDITIONS VARY AMONG SUBAREAS

Effects of Increasing Water Quantities on Crop Choices and Irrigation Practices Vary among Subareas

Data in the previous section show how total farm net returns-over-variable expenses rise in all subareas as water prices decline, or as quantities increase with prices constant. The declines in added net returns accompanying added water quantities indicate why these total net returns increase at a diminishing rate; additional value products accompanying each added acre-foot of water lessen as total water quantities expand. Underlying these decreases are the variations among crops in net returns-over-variable expenses. A linear programming analysis based on System C for each of the four analytical models determined that cotton

offers the highest net returns-above-variable expenses for initial water increments (see Figure 8). According to these results, before allocating water to any other irrigated crop, farmers can obtain the maximum potential total farm net returns by applying all available irrigation water to cotton on the best quality lands up to the maximum 200-acre allotment in each of the four subareas.

Results from analyzing these models indicate that the several subareas differ in optimum irrigation treatments for cotton, as identified by maximum total farm net returns-over-variable expenses. As available quantities increase, maximum returns to the model for Upper accompany shifts first to medium, and then to the wet treatment at very early increments for water supply. The Central model, in contrast, shows highest net returns associated with the dry treatment almost up to the maximum for water quantities. At this stage, gains result from shifting first to medium, and then finally to wet cotton irrigation practice (see Figure 8). Data for the Westside model show maximum net returns to the medium treatment, except that an advantage results from shifting approximately one-third of the cotton acreage to the wet treatment at almost the maximum total quantity of water available.

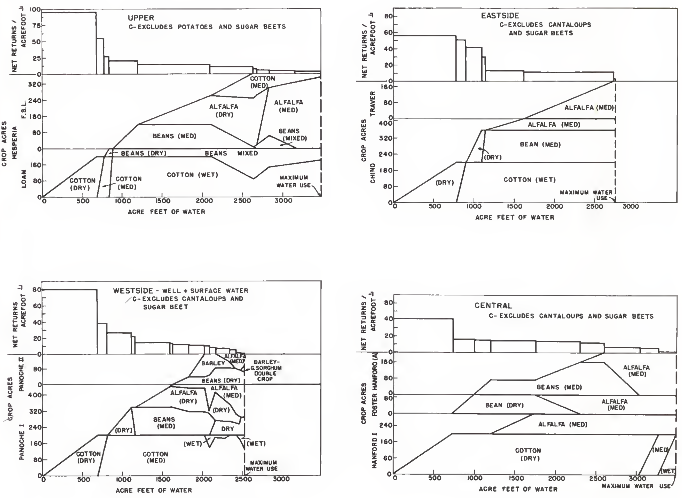
The next crop to come into the farming programs as water quantities increase in all four subareas is Blackeye beans. This crop also is under the dry treatment in all four subareas and on Grade I soil in all subareas except Central. In the latter, operators can maximize total farm net returns under conditions of this study by using additional water (after all allowable acreage is in cotton) to plant Blackeye beans on the Grade III soil, a loam. Some Grade II soil also comes into the program for the Central subarea model before all Grade I soil is used; beans, under medium irrigation treatment, occupy this land.

Additional water quantities after the first increments applied to cotton and Blackeye beans in all four subareas result in three common shifts: First, bringing land other than Grade I into use; second, shifting from the drier to the wetter irrigation treatments for all crops; third, introducing alfalfa into the cropping programs (see Figure 8).

The higher water costs in Westside and Upper explain the relatively large number of cropping program adjustments in these two subareas (see Figure 8). A fairly large initial water application is required to irrigate the entire cotton

FIGURE 8

CHANGES IN CROP ACRES AND ADDED NET RETURNS PER ACRE-FOOT OF WATER AT VARYING QUANTITIES OF IRRIGATION WATER; FOUR SUBAREAS



acreage allotment (650 to about 780 acre-feet for Upper, Central, and Westside, and 900 for Eastside). Small additions at the relatively high constant cost, then, usually are adequate to cause changes in irrigation treatments, crops selected, or acres allocated. This is less evident for Eastside for quantities above approximately 1,650 acre-feet and for the range of increments between approximately 1,300 and 2,700 acre-feet in Upper. Net returns per added acre-foot accompanying changes in water quantities show sharp decreases in magnitude after the initial water increments (see Figure 8). These changes, plus resultant shifts in irrigation treatments, crops selected, and acreage allocations, suggest some of the general relationships that govern farmers' success in adjusting cropping programs to maximize total farm net returns-over-variable expenses as water quantities increase. These additional net returns per acre-foot (marginal value products) differ from those cited in Table 5 in that these data have been adjusted to eliminate variable water costs. Thus, for Upper the average additional net returns per acre-foot for the first 1,676 acre-feet of water is $96.88 with $4.50 per acre-foot for irrigation water already subtracted in arriving at total farm net returns. After adjusting for water variable costs, the additional net returns per acre-foot is $101.38 ($96.88 plus $4.50). This adjustment makes additional net returns per acre-foot comparable among subarea models; it corrects for variations in water variable costs among these subareas. Data for the four models show wide variations in additional net returns per acre-foot of added irrigation water (see Figure 8). Initial values, ranked according to magnitude, are Upper $101.00, Westside $90.00, Eastside $59.00, and Central $43.00. Extremely sharp reductions in additional net returns per acre-foot occur for water increments after the initial quantity (applied entirely to cotton) for both Upper and Westside; the drop for Central is sharp but of lesser magnitude, that for Eastside decidedly smaller. Relatively sharp drops occur for this model at about 1,200 and 1,250 acre-feet; drops for the other three models are relatively slight at each of the successive water increments (see Figure 8).

Several interrelated factors explain the variations among subarea models in total farm net returns, crop choices, and acreage allocations among crops. The basic criterion for identifying and comparing solutions in this analysis is maximum total farm net returns-over-variable expenses under each set of conditions. Absolute and relative net returns per acre for individual crop-soil-irrigation treatment combinations, in turn, are critical factors affecting total

farm net returns.[1] Several important factors and forces govern these net returns per acre; water requirements per acre, water prices (variable costs), other input costs, yields, and product selling prices.

The widest range of variation among the subarea models in additional net returns per acre-foot is for the initial increments of irrigation water allocated entirely to cotton. These variations reflect primarily the differences in cotton yields among subareas, although other less critical factors have some bearing. Much less variation exists among subareas in the magnitude of net returns per acre-foot accompanying later irrigation water increments (see Figure 8).

Water Costs Strongly Influence Cropping Programs in all Subareas

A linear programming analysis in which water prices (variable costs) vary from zero to $32 per acre-foot shows that important adjustments in cropping programs and water use for analytical models accompany such variations in all subareas (see Figure 9). The general adjustment pattern to maximize total farm net returns-over-variable expenses is quite similar among the four subareas. Farm operators idle all land except that in cotton at a much lower water price (approximately $18 per acre-foot) in Central than in any other subarea; in general, a sharper reduction in water use accompanies one dollar increase in water variable cost for this subarea as compared with the other three. Two subareas, Upper and Eastside, show extremely sharp reductions in water use as continuing rises bring prices to the $15-$16 range (approximately 50 percent reduction in each instance) as compared with quantities used at zero prices.

Data on crop choices and acreages according to soils and irrigation treatments indicate a common pattern in all subareas for shifts through five cropping plans in Upper and Westside and four in Eastside and Central. In the cropping plan at the lowest water variable cost (Plan I) for each subarea, crops occupy all tillable land, and the combination of crops and irrigation treatments utilizes the largest quantity of water in the total water price range (see Figure 9). Upper and Central models include only cotton and alfalfa, with the cotton irrigated

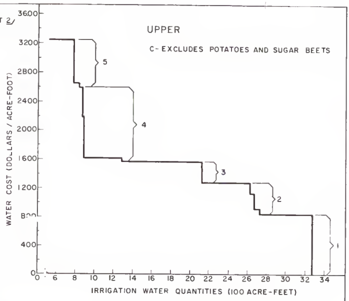
- -

1/ Net returns per crop acre as used in this analysis do consider variable water costs, in contrast to the adjusted marginal value products, which latter values, as already explained, do not. Thus, differences in water costs among subareas affect net returns per acre and cropping programs, although variations among subareas in average marginal value products have been eliminated by the adjustment for water price differential.

FIGURE 9

OPTIMUM CROPPING PLANS FOR CRITICAL RANGES OF IRRIGATION WATER VARIABLE COSTS; FOUR SUBAREAS

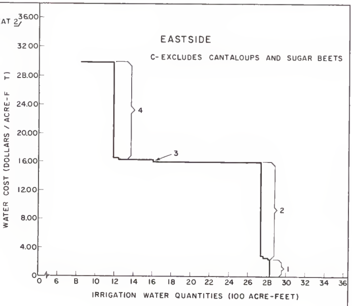
PLAN	CROPS	ACRES	SOIL 1/	IRR TREAT 2/
(5)	COTTON	200	H L-I	2
	B BEANS	41	H L-I	1
	IDLE	361	H S-I	1
	TOTAL	602		
(4)	COTTON	200	H L-I	4
	B BEANS	41	H L-I	1
	IDLE	361	H S-I	1
	TOTAL	602		
(3)	COTTON	200	H L-I	4
	ALFALFA	151	H S-I	1
	B BEANS	41	H L-I	3
	B. BEANS	119	H S-I	2
	IDLE	91	H S-I	
	TOTAL	602		
(2)	COTTON	100	H L-I	4
	COTTON	100	H S-I	2
	ALFALFA	242	H S-I	1
	B. BEANS	141	H L-I	2
	B BEANS	19	H S-I	2
	TOTAL	602		
(1)	COTTON	185	H L-I	4
	COTTON	15	H S-I	2
	ALFALFA	346	H S-I	2
	ALFALFA	56	H L-I	3
	TOTAL	602		



1/ H = HESPERIA, L = LOAM, S = FS LOAM

2/ IRRIGATION TREATMENTS. 1 = WET, 2 = MEDIUM, 3 = MIXED, 4 = DRY

PLAN	CROPS	ACRES	SOIL 1/	IRR TREAT 2/
(4)	COTTON	200	C-I	4
	B BEAN	160	C-I	2
	IDLE	61	C-I	
	IDLE	181	T-II	
	TOTAL	602		
(3)	COTTON	200	C-I	4
	ALFALFA	61	C-I	2
	B.BEANS	160	C-I	2
	IDLE	181	T II	2
	TOTAL	602		
(2)	COTTON	200	C-I	4
	ALFALFA	61	C-I	2
	ALFALFA	181	T-II	2
	B BEANS	160	C-I	2
	TOTAL	602		
(1)	COTTON	200	C-I	4
	ALFALFA	79	C-I	2
	ALFALFA	181	T-II	2
	B BEANS	142	C-I	2
	TOTAL	602		

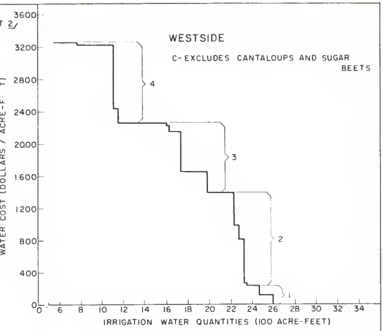


1/ C = CHINO, T = TRAVER

2/ IRRIGATION TREATMENTS:
2 = MEDIUM, 4 = DRY

FIGURE 9 CONTINUED

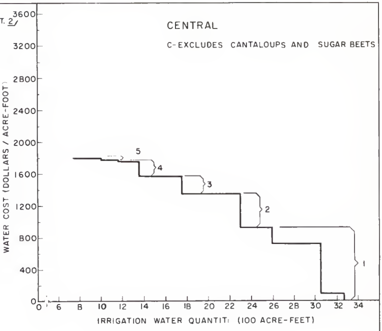
PLAN	CROPS	ACRES	SOIL 1/	IRR TREAT 2/
(4)	COTTON	200	P-I	2
	B BEANS	160	P-I	1
	IDLE	151	P-II	
	IDLE	91	P-I	
	TOTAL	602		
(3)	COTTON	200	P-I	2
	ALFALFA	91	P-I	3
	B. BEANS	160	P-I	2
	IDLE	151	P-II	
	TOTAL	602		
(2)	COTTON	200	P-I	2
	ALFALFA	113	P-I	2
	ALFALFA	72	P-II	2
	B BEANS	138	P-I	1
	BARLEY	57	P-II	1
	TOTAL	602		
(1)	COTTON	200	P-I	4
	ALFALFA	91	P-I	2
	ALFALFA	98	P-II	1
	B BEANS	76	P-I	2
	BAR/G S	85	P-I	1
	BARLEY	52	P-II	
	TOTAL	602		



1/ P= PANOCHE

2/ IRRIGATION TREATMENT: 1= WET, 2= MEDIUM, 3= MIXED, 4= DRY

PLAN	CROPS	ACRES	SOIL 1/	IRR. TREAT. 2/
(5)	COTTON	200	H-I	1
	IDLE	101	H-I	
	IDLE	211	H-II	
	IDLE	90	F	
	TOTAL	602		
(4)	COTTON	200	H-I	1
	B BEANS	101	H-I	2
	B.BEANS	59	F	1
	IDLE	211	H-II	
	IDLE	31	F	
	TOTAL	602		
(3)	COTTON	200	H-I	1
	ALFALFA	101	H-I	2
	B BEANS	70	H-II	2
	B BEANS	90	F	1
	IDLE	141	H-II	
	TOTAL	602		
(2)	COTTON	200	H-I	1
	ALFALFA	101	H-I	2
	ALFALFA	51	H-II	2
	ALFALFA	90	F	2
	B BEANS	160	H-II	2
	TOTAL	602		
(1)	COTTON	200	H-I	4
	ALFALFA	101	H-I	2
	ALFALFA	211	H-II	2
	ALFALFA	90	F-III	
	TOTAL	602		



1/ H=HANFORD, F= FOSTER

2/ IRRIGATION TREATMENTS: 1= WET, 2= MEDIUM, 4=DRY

under the wettest treatment, while Eastside includes Blackeye beans and Westside -- beans, barley-grain sorghum double-cropped, and barley.

The sequential order for adjustments to increasing water costs that occur among these plans is quite similar in each of the four subareas:

1. Alfalfa acreage declines as that in Blackeye beans, a lower water-use crop, increases;

2. Alfalfa and/or cotton receives a drier treatment (2 or 1) instead of the wet treatment (4);

3. A portion of the land remains idle; and

4. Still more land is idled, including even that portion of the Grade I soil that exceeds cotton acreage allotments.

One further adjustment, in addition to these four, may be forced on farmers facing still higher water prices, or other drastically unfavorable conditions -- to cease farming and go out of business. Most growers accept this final adjustment only under the most adverse conditions. They may, for a time, accept zero returns for management and below-market rates of return for capital, sometimes actual capital losses, rather than quit farming.

A combination of soil quality variations and differences among crops in net returns per acre largely explains the variations among subareas in reduced water use (and associated cropping program adjustments) that accompany increased water variable costs. Thus, approximately $16 per acre-foot is the highest price under cost and price relationships in this study at which alfalfa will return enough in gross receipts to cover water costs on the low grade soils in all subareas. Land in this crop, therefore, goes out of production in all subareas except Westside at about $16 per acre-foot: Only 91 acres of alfalfa appear under Plan 3 in Westside; it is on Grade I soil and receives a mixed irrigation treatment. Blackeye beans, a low water-use crop, still remains in cropping plans at the highest water price examined for all subareas except Central. In this latter subarea, all land not in cotton is idle at approximately $18 per acre-foot, a relatively low water variable cost in comparison with those permitting beans to be produced in other subareas.

These data for farming System C (excluding specialty crops and sugar beets) in all subareas, indicate that farmers seeking maximum net returns have no economic alternative to reducing water use sharply at prices higher than $16 per acre-foot. Under conditions of this study cotton is the only relatively

high net return crop among their alternatives, and government regulations limit acreage and production for this one. A similar analysis including sugar beets (a 72-acre proportionate share) for System B on the Eastside shows 181 acres of (Grade II) soil idle at the upper extreme for water variable costs ranging from \$26-\$30 per acre-foot.[1/] Other than cotton, only Blackeye beans could cover costs with water variable costs at \$25-\$28 per acre-foot. Similar results could be expected from a similar analysis for the other three subareas. The ability of cotton-general crop farmers in all subareas to use profitably appreciable quantities of water beyond those required for cotton evidently rests upon being able to grow specialty crops yielding relatively high net returns per acre.

Subareas Vary in Quantities of Water Used at Specified Prices; All Reduce Use as Prices Increase

A linear programming analysis in which prices vary from zero to approximately \$32 per acre-foot indicates that optimum solutions for each of these farm models would come at progressively fewer acre-feet of water used, as water prices rise. Among the four analytical models, Central and Upper indicate the highest quantities of water used at zero prices according to conditions of this study (approximately 3,500 acre-feet for System C (see Figure 10)).

This analysis includes System C in Central and all three systems (A, B, and C) in the other three subareas. It includes data for both ground and ground-plus-surface water sources in Westside. The "bench" effect observed in the preceding section at about \$15-\$16 per acre-foot shows again in this analysis for Upper and Eastside, and to some extent in Central. A similar sharp decrease in water use accompanying a price increase is evident at prices between \$22-\$24 per acre-foot for Westside (see Figure 10 -- Westside).

Potatoes and sugar beets in Upper, and cantaloups and sugar beets on the Eastside tend to minimize the bench effect already noted for System C (see Figure 10). These relatively high return crops that can remain in production as water prices rise above the \$16 level occupy land that otherwise would become idle when high water prices eliminate alfalfa. This effect is less evident

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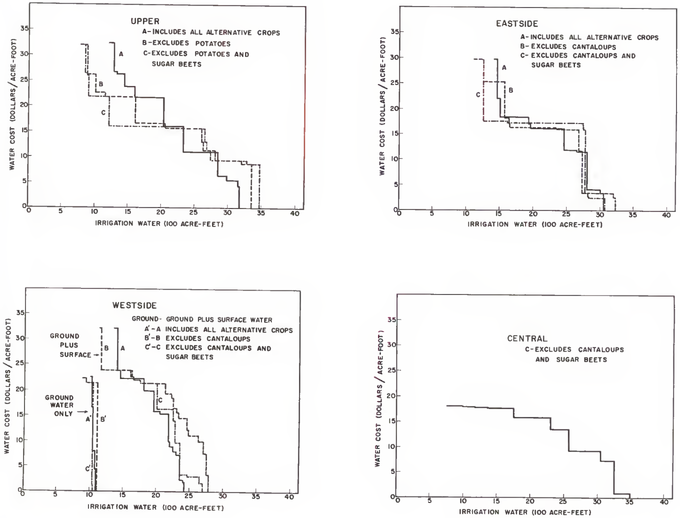
1/ Hedges and Moore, Economics of On-Farm . . . . 1. Enterprise Choices, Resource . . . , p. 54.

FIGURE 10

SHORT-RUN FARM DEMAND FOR IRRIGATION WATER; FOUR SUBAREAS



for Westside, as might be expected from the previous section, but is recognizable for this subarea in System A. Changes in water quantities in response to price rises are relatively minor for ground-water-only conditions on the Westside; this is because water quantities at the minimum price allow little margin above the amounts required by the cotton acreage allotment.

FARM PROFIT DIFFERENTIALS AMONG SUBAREAS COVER A WIDE RANGE

A comparison among subareas in total farm profits and other earnings measures affords a useful indication of the economic differences among the four analytical models under conditions of this study. This is true even though such a comparison must depend in considerable degree upon estimates and imputed data. We use the System C model and typical water variable costs in each subarea to calculate profits. The first step is to subtract total farm fixed costs from net returns-over-variable expenses at the optimum solution for each of these four models at the estimated typical water prices for the various subareas (Upper $4.50, Eastside $3.00, Westside $9.50, and Central $1.75). The resulting value for net returns-over-fixed costs plus variable expenses ranges from $4,630.00 for Westside, ground water-only, to $26,580.00 for the model representing the Upper San Joaquin Valley (see Table 6). It is necessary, second, to adjust this net figure in order to calculate standard farm earnings measures. This step involves adding back to the net returns data the amounts previously deducted for the value of the operator's own work in the field ($1,800.00 in each model), and for interest on capital invested in the farm plant.

NET FARM INCOME, determined by the previous step, is a standard farm earnings measure, but it has limited usefulness because it combines one return properly belonging to the operator for his own labor, another representing the reward for his management, and still a third representing interest on the capital invested in the farmland, improvements, and equipment. This net farm income measure also was highest for Upper ($66,440) in this study, and least for Central ($36,740). Little difference is evident between the other two models (see Table 6).

Total PROFIT, or capital and management income, to the entire farm business results from step three, subtracting an allowance for the operator's full time (imputed at the going rate for hired labor) from net farm income. This value for Upper ($62,840 is almost double that for Central ($33,140); the other two

TABLE 6

Farm Profits (Capital and Management Income); 640-Acre Farm in Four Subareas, 1956-1960 Conditions

Item	Upper	Eastside	Westside		Central
			Ground-water-only	Ground-plus-surface water	
	1	2	3	4	5
	dollars				
TOTAL FARM CAPITAL a/	634,293	505,885	566,717	566,717	381,072
Gross receipts less variable expenses b/	99,750	83,250	65,995	85,200	61,105
All fixed costs	73,169	64,000	61,364	67,124	49,031
NET RETURNS OVER FIXED COSTS	26,581	19,250	4,631	18,076	12,074
Add					
Value operator's work c/	1,800	1,800	1,800	1,800	1,800
Interest on capital d/	38,058	30,353	34,003	34,003	22,864
NET FARM INCOME	66,439	51,403	40,434	53,879	36,738
Subtract					
Operator's wage e/	3,600	3,600	3,600	3,600	3,600
PROFIT (return to capital and management)	62,839	47,803	36,834	50,279	33,138
Interest on farm capital at 6 percent	38,058	30,353	34,003	34,003	22,864
MANAGEMENT INCOME	24,781	17,450	2,831	16,276	10,274
RATE EARNED (percent)	9.91	9.45	6.50	8.87	8.69

Sources: a/ See Table 1.
b/ Net returns-over-variable costs at typical water variable costs per acre-foot, as calculated by the authors (see Table 4 and Figure 6).
c/ Imputed by authors.
d/ See Table 2.
e/ Imputed by authors.

subareas rank in between, with the return to Westside, ground water-only, distinctly the lowest of the three profit values calculated for these subareas.

Another measure, MANAGEMENT INCOME, results from subtracting interest on farm capital investments at the going rate of interest (assumed to be 6 percent in these calculations) from profits. Inasmuch as average total farm investments vary markedly among the four subareas, so also do the imputed values for interest and those for management income obtained by subtracting the interest on investments. Upper, with $24,780 for management income, shows by this measure more than eight times as high earnings as Westside, ground water-only, and more than double those of Central (see Table 6). Eastside and Westside with both ground and surface water available compare more closely than any of the other management income values.

These earnings comparisons underscore the important differences already discovered among the several subareas. They indicate a close interplay of income effects on the farms involved between physical productivity (as governed by soil quality, quantities of water, and other resources) and water costs. Upper has the most productive soil resources as these four models are synthesized, all being of Grade I, but has the second highest variable cost for irrigation water. The high soil productivity, plus adequate quantities of water, permit high yields for cotton, in particular, and for the supplementary crops in the C System. These advantages explain the first rank status of the model for Upper in every earnings measure used here. Water costs, although second only to Westside, do not prevent this favorable earnings ranking.

The model for Central, the lowest ranking subarea according to earnings, is not able to capitalize on its extremely low water variable cost level, due to less favorable production opportunities. Soils include Grades I, II, and III, and marginal climatic characteristics also limit cotton yields; other crops fail to offset this handicap.

The critical importance of adequate supplies of irrigation water is evident from the low earnings performance of the Westside model based on ground water-only, although high variable costs for water also contribute to these unfavorable returns. The most specific evidence of how relatively high water costs react upon earnings is available from comparing the earnings for Eastside and Westside ground-plus-surface water. In spite of the relatively more favorable soil resources and higher cotton yields in Westside, no sharp differences

appear in the earnings measures used here. Somewhat higher values for net farm income and profit are associated with lower management income in the Westside due to higher investments and interest on investments in this subarea.

Two other points are important in these earnings comparisons. First, more complete information regarding how variations in quantities of water available, and in the variable costs for irrigation water, affect farm returns performance appears in the earlier sections of this report. These data, due to the analytical approach, do not identify associated changes in profits and other earnings measures. Second, the earnings comparison presented here is for the System C model, only, in each subarea, and does not reveal how including the specialty crops in Systems A and B models would affect earnings. This limitation is unavoidable if all four subareas are to be included in the comparison, inasmuch as Central includes only the System C model.

A word of caution is appropriate regarding interpreting and using the data for total farm investments, and how these data relate to profits. Much of the dollar total for farm investments and annual fixed costs in each of the subareas represents land values. To the extent that the actual land values per acre in any subarea at any time differ from these estimates, therefore, any interpretations based upon the valuations appearing here for land values per acre and for total farm investments can be highly misleading. We do not claim that these valuations precisely reflect land market conditions even at the time of the study. On the contrary, we know that actual land transfers at definitely higher prices occurred in all subareas during the time that interviews were in progress. We do recommend these total farm investment data, however, as a reasonably adequate indication of the variations among subareas in farm capital requirements. This is not to say that the land values and other estimates for property valuations reflect precisely even the variations among subareas in farm investments, but, rather, that the range of error is acceptable for the purpose of making comparisons among these subareas. Thus, the land values and other estimates for property investments are useful for <u>relative</u> comparisons, but not as indicators of <u>absolute</u> values. This same principle holds for interpreting the meaning of the profits and other earnings measures based upon these estimates; they are not reliable as measures of <u>absolute</u> earnings levels, but only of the <u>relative</u> levels among subareas.

Specialty crops also offer profit opportunities (in many instances comparable with cotton on a per-acre basis) to the farmer who is in the position to

produce them. But the opportunity for expansion in such crops appears limited to associated changes in population and the market, according to other economic analyses. We see no evidence in our investigations, therefore, that the overall relationships indicated by this study are likely to shift materially in the immediate future, assuming no important changes in the general economy and price level. Adequate supplies of irrigation water at variable costs not exceeding \$12-\$15 per acre-foot will continue to be essential for 640-acre cotton-general crop farms to operate profitably in the San Joaquin Valley. Other reports in this series include evidence indicating that smaller farms require even lower variable water cost levels for profitable operation.

FEDERAL INCOME SUPPORTS AND PRODUCTION CONTROLS LIMIT COTTON OUTPUT; AFFECT EARNINGS

Cotton Price Supports and Acreage Allotments Dominate Decisions

A choice between Plans A and B was available to growers under the Agricultural Stabilization and Conservation Act in 1959 and 1960. Except for those years, from 1954 to 1964, California cotton producers could expect approximately 33 cents per pound from their cotton, assuming average quality. But, as a condition for this supported price, those operating 640-acre farms such as the models analyzed here were limited to about 200 acres of cotton (of 602 acres tillable land). It is important, in light of the marked earnings superiority that cotton displays over all other alternative (except specialty) crops, to examine what might be the result from eliminating income supports and acreage allotments.

For several years the United States Government has subsidized commercial cotton exports at rates varying from 8.5 cents per pound of lint during the 1961-1962 through 1963-1964 (1 August through 31 July) marketing seasons to 5.75 announced initially for 1965-1966. More recently, under legislation passed on 11 April 1964, the Government also pays 6.5 cents per pound of lint as a subsidy on cotton used in domestic mills.[1/] It can be assumed that prices paid farmers for cotton lint would drop sharply from the 33 cents per pound of lint used in this study if price supports, including related subsidies to foreign and domestic users, were no longer available. The results we present here in earlier sections suggest

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1/ Cotton Situation, Econ. Res. Ser., U.S. Department of Agriculture, CS-212, May 1964, page 4, CS-217, March 1965, page 4, and earlier issues.

that farmers can obtain higher earnings from cotton than from other crops at definitely reduced cotton prices. If true, this indicates a cotton earnings advantage strongly supporting the validity of the above assumption. Still more direct evidence exists in the records of farmer cotton decisions and production in California and other western states under the Plan A - B program.

Under Plan B growers were entitled to plant acreages exceeding their allotments by up to 40 percent under the condition that their cotton price support level would be reduced 15 percentage points of parity from that applying to Plan A (with regular acreage allotments). California growers increased plantings by an additional 180,000 acres over the aggregate state base in 1959 and by 239,000 acres in 1960 under the Plan B conditions; they and other western growers accounted for 232,000 acres in 1959 and 348,000 acres in 1960, in comparison with total national increases of 1,108,000 acres in 1959 and 1,218,000 acres in 1960.1/

Thus in California and other western states important acreage increases permitted under reduced price support, as compared with regular allotments at the higher price support levels, brought markedly higher cotton production during the 1959 and 1960 seasons.

A linear programming analysis in which cotton lint prices vary from zero to approximately 42 cents per pound provides useful indications of what changes in cotton lint production <u>might</u> occur if cotton lint prices were not supported, and if farmers were free to make decisions without acreage restrictions. The results of this analysis are available for all three cropping systems (A, B, and C) tested in three of the four subareas, and also for the ground-water-only conditions in Westside (see Figure 11). This analysis is within the same framework, except for free market conditions on cotton, as the earlier analyses in this report; water prices (variable costs), constant in each subarea at the predetermined levels indicated earlier, vary among them. Cotton comes into the farming program in this analysis when two conditions are satisfied; first, it must show positive net returns per acre, second, these returns must be higher than those available from other alternative crops.

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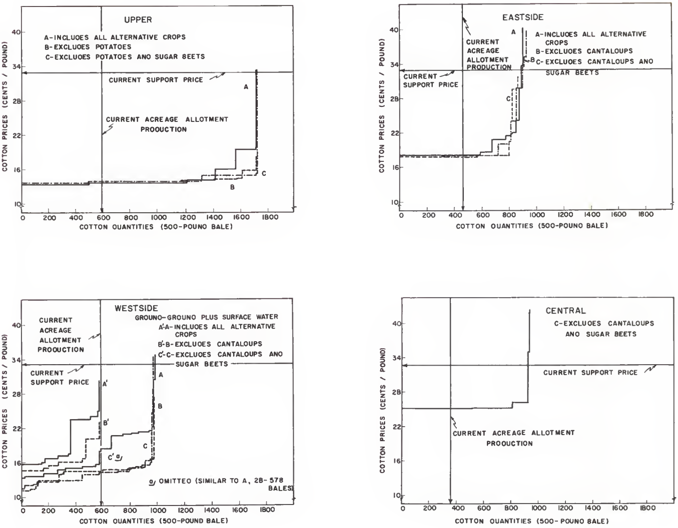
1/ <u>The Cotton Situation</u>, U.S. Department of Agriculture, A.M.S., May 1959 and 1960. See also, Caton, Douglas D., and Trimble R. Hedges, <u>An Evaluation of Allotment Plans A and B on California Cotton Farms in 1959</u>, Berkeley: University of California, Agricultural Experiment Station, Giannini Foundation of Agricultural Economics Mimeo. Report No. 215, February 1959.

FIGURE 11

COTTON PRODUCTION AT VARYING LINT PRICES; FOUR SUBAREAS



Indications are that cotton would displace other crops, and come into the cropping system, at prices less than 20.0 cents per pound of lint for all subareas except Central, and at 25.1 cents per pound in this subarea. In contrast to Central, operators should begin allocating land to cotton when the lint price reaches 11.2 and 11.6 cents per pound, respectively, for C and B systems for the San Joaquin Valley Westside (ground-plus-surface water unit) and at prices of 13.4-13.6 cents for the A system on the Westside and all three systems in Upper. Lint prices of 18.0-18.4 cents would bring cotton into the cropping programs in the San Joaquin Valley Eastside (see Figure 11 and Table 7). Once lint prices rise to the point that cotton is able to displace other crops in the farming programs, a relatively small additional price gain causes sizable acreage shifts from other crops into cotton, and sharp increases in lint production.

Except for Central, these shifts bring practically all Grade I soil into cotton production at prices of 20.0 cents, or slightly higher, per pound of lint in order to maximize net farm returns. The A and B systems require slightly higher lint prices to displace specialty crops in favor of cotton. Even in Central a gain of only 1.1 cents per pound from the 25.1 cent price at which cotton enters the cropping program causes production to increase from 516-825 bales (see Table 7). Further cotton lint price rises beyond 20.0-22.0 cents per pound have little effect toward increasing cotton production on any of these models except the one for Central. This is because earlier price gains up to the 22.0 cent level are adequate to cause most of the available acreage to be shifted.

The Upper San Joaquin Valley model shows the greatest total cotton production in this analysis, about 1,730 bales as compared with approximately 1,000 for each of the other subareas (except 600 for Westside, ground-water-only conditions). The greater cotton production response in Upper reflects the fact that all soil is classed as Grade I in this model.

The approach used in this analysis does not attempt to measure or evaluate several factors that would operate if the Government actually were to end price supports and acreage restrictions for cotton. One such excluded factor that could exert considerable influence is accompanying changes in acreages and production of alternative crops, such as alfalfa hay, and the related impacts that such shifts could have on relative prices for the products and on their

TABLE 7

Cotton Lint Production at Varying Prices; Four Subareas (500-pound gross-weight bales)

Net Returns	Price	Production	Net Returns	Price	Production	Net Returns	Price	Production
1	2	3	4	5	6	7	8	9
dollars		bales	dollars		bales	dollars		bales
A. Includes All Alternative Crops			B. Excludes Potatoes			C. Excludes Potatoes and Sugar Beets		
Upper San Joaquin Valley								
54,668	.000	000	45,090	.000	000	42,198	.000	000
54,668	.134	259	45,090	.136	265	42,198	.136	497
54,979	.136	502	45,122	.137	497	42,332	.136	666
55,976	.140	1,218	46,181	.140	1,179	42,542	.137	711
68,358	.161	1,432	46,747	.141	1,423	43,705	.140	1,319
93,157	.195	1,566	46,982	.142	1,575	44,006	.140	1,615
94,744	.197	1,728	60,304	.158	1,626	44,782	.141	1,728
212,096	.333	1,730	61,308	.160	1,736	78,456	.180	1,735
			211,679	.333	1,736	211,028	.333	1,736
A. Includes All Alternative Crops			B. Excludes Cantaloups			C. Excludes Cantaloups and Sugar Beets		
San Joaquin Valley Eastside								
65,989	.000	000	51,973	.000	000	48,915	.000	000
65,989	.184	478	51,973	.180	4	48,915	.180	420
66,916	.188	593	52,047	.183	332	49,402	.183	564
73,593	.211	680	52,171	.184	712	49,876	.184	730
75,183	.215	787	60,616	.208	807	57,572	.205	731
75,372	.216	800	73,944	.240	823	58,150	.207	800
76,829	.219	801	97,783	.298	829	63,650	.221	818
77,445	.221	825	98,385	.300	856	98,354	.306	853
86,695	.243	856	99,470	.302	864	102,151	.314	892
109,917	.298	866	105,158	.315	867	111,090	.334	893
127,763	.339	882	114,551	.337	881	138,995	.397	894
159,865	.412	899	121,754	.353	885			
San Joaquin Valley Westside (Ground-plus-surface water)								
48,961	.000	000	34,550	.000	000	32,747	.000	000
48,961	.135	2	34,550	.116	8	32,747	.112	5
48,963	.138	34	34,615	.123	34	32,753	.115	54
49,016	.141	177	34,633	.124	94	33,108	.126	106
49,656	.148	272	34,841	.128	129	33,289	.130	113
50,081	.151	331	35,695	.141	284	33,870	.140	451
50,292	.152	457	35,716	.142	308	34,905	.145	560
51,251	.156	554	36,492	.147	320	35,511	.146	724
57,985	.180	578	36,685	.148	604	37,028	.151	799
58,764	.183	593	37,058	.149	787	37,389	.152	901
66,443	.208	670	38,337	.152	815	42,858	.164	923
66,494	.209	745	38,673	.153	845	43,433	.165	953
67,029	.210	823	40,420	.157	891	67,422	.215	967
69,282	.216	872	42,135	.161	960	88,032	.256	969
69,882	.217	949	45,072	.167	977	105,676	.294	972
71,485	.220	975	97,117	.274	984	130,027	.344	977
112,942	.305	984						
134,488	.349	990						
San Joaquin Valley Westside (Ground-water-only)								
35,540	.000	000	20,516	.000	000	19,841	.000	000
35,540	.158	136	20,516	.145	24	19,841	.140	28
35,732	.160	152	20,621	.152	165	19,910	.145	181
36,214	.167	171	20,818	.155	218	20,957	.156	213
36,646	.171	272	21,586	.161	271	21,813	.165	301
36,879	.173	347	22,298	.167	455	23,962	.178	333
47,810	.234	363	30,650	.201	479	24,461	.181	410
48,500	.238	521	31,576	.204	576	24,939	.184	538
51,829	.251	566	36,761	.223	577	29,659	.201	576
56,847	.268	576	36,868	.230	578	58,163	.300	578
67,008	.304	578						
Central San Joaquin Valley								
						49,073	.000	000
						49,073	.251	516
						52,008	.262	825
						86,737	.347	936
						121,198	.420	940
						123,076	.424	946

contributions to total farm earnings. As we point out above, differences in soils among subarea models are highly important in explaining production variations among them under free market conditions. In addition to soil factors, water conditions also may operate as a limiting factor in these adjustments to rising cotton prices. This is because the analytical framework for the study reflects a short-term situation. All shifts, therefore, must come within the fixed resource complement for each of the subarea models; time is not available to drill more wells or otherwise improve resource conditions.

A further point is important here; this analysis disregards enterprise interrelationships and other intrafarm limitations on continually expanding cotton acreage, such as declining yields per acre. Quite possibly, under such acreage shifts as indicated here, some of these forces might either interfere at some point with continued shifts from other crops to cotton, or cause cotton yield declines of such magnitude as to discourage additional shifts.

This analysis, subject to the indicated limitations, indicates that cotton production on 640-acre farms similar to these models quite possibly would be markedly higher in all four subareas if acreage restrictions were removed, even at the decidedly lower prices that probably would prevail in the absence of restraints on production. Thus actual production for the model in Upper San Joaquin Valley, as specified in this study under existing Government price supports and acreage regulations, is 570 bales produced on 200 acres. In contrast, this same price, estimated at 33.0 cents per pound, in the absence of acreage allotments, would call for maximum cotton lint production for all three farming systems (A, B, and C) -- about 1,730 bales (see Figure 11). Similar relationships are evident for the other three subareas. This finding is further supported by the relatively low lint prices at which cotton would displace other crops on the Grade I soil in this analysis based on maximizing total farm net returns. This comparison of the production levels that likely would exist in the absence of Government programs, and those specified for the four models under existing programs, underscores the marked advantage that cotton displays in this study over other crops in net returns-over-variable expenses per acre.

It is possible, using estimates for cotton lint production in the absence of Government programs, to compare the relationship between total farm net returns-over-variable expenses and total farm fixed costs under these estimated conditions with those determined for conditions existing in this study. Such

examination, with water prices (variable costs) at the level specified in this study ($4.50, $3.00, $1.75, and $9.50 per acre-foot for Upper, Eastside, Westside, and Central, respectively), indicates that break-even cotton lint prices would be about as follows: Upper 17.25, Eastside 22.50, Westside 21.50, and Central 25.10 cents per pound of lint.

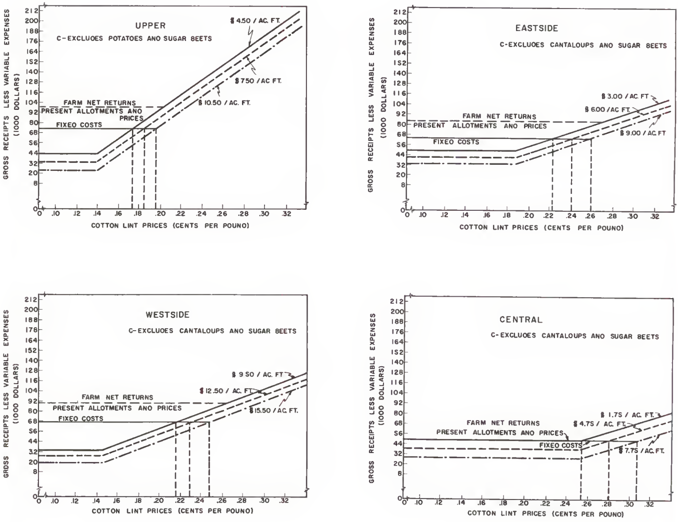
At these typical water prices for the four subareas, therefore, these analytical models each show total farm net returns equal to total farm fixed costs at decidedly lower cotton lint prices than the 33.0 cents assumed under Government price supports. But cotton production would be at sharply higher levels at these lower prices than under the existing support levels. Thus, for the C farming system in Upper, about 1,730 bales of cotton lint would be produced at the 17.25 cent cotton lint prices under which farm net returns break even with total farm fixed costs. Similar relationships (decidedly higher cotton production at lower lint prices for solutions in which total farm net returns break even with fixed costs) are evident for the other subareas, except Central.

We also examined the effects of higher water prices in each subarea, assuming no Government price supports or acreage restrictions for cotton. The result of this further analysis is lower levels of total farm net returns-over-variable expenses at each solution, and, consequently, higher cotton lint prices necessary for break-even relationships between net returns and total farm fixed costs (see Figure 12). Little increase in cotton production could result for Upper and Westside models under these cotton lint price conditions, furthermore, because estimated production at the lower prices already is near the maximum potential; some gains are indicated for the other two subareas.

The preceding analysis clearly indicates that farmers in the San Joaquin Valley should not expect much improvement in their ability to pay for irrigation water as a result of increased cotton returns. In the absence of acreage restrictions, farmers could produce a great deal more cotton at lower prices than they are permitted to do under existing price supports and acreage allotments, but might gain little earnings advantage. Some further increases in cotton yields per acre might occur to strengthen cotton earnings in some degree, of course, providing lint prices remain unchanged after the yield increase, or drop less than in proportion. Certainly it does not appear reasonable to expect further rises in cotton <u>prices</u> above existing support levels. American and California producers continue to depend upon foreign outlets for a major

FIGURE 12

FARM NET RETURNS WITHOUT ACREAGE ALLOTMENTS UNDER VARYING COTTON LINT PRICES; FOUR SUBAREAS



proportion of the total cotton market; government subsidies on commercial marketings plus the problems arising from competition of synthetic textiles suggest that cotton support prices are unlikely to rise in relative terms.

The opportunity to expand production in the absence of acreage restrictions is greatest in Upper and Westside but is important in both the other subareas. A major reason is the much greater proportion of all soil resources classified as Storie Grade I (80-100 percent on the Storie Index) in these subareas as compared with the other two. Again, this analysis does not consider certain factors that might operate to reduce the degree of production response to rising cotton lint prices in the absence of cotton acreage allotments. It ignores, furthermore, the impact that shifting sizable acreages from cotton to other crops might have on aggregate production, prices, and net returns from these alternative crops in the study area. In spite of these omissions from the analysis, however, the results indicate that farmers should look to some crop or crops other than cotton for major increases in total farm net returns and water purchasing capacity.

CONCLUSIONS

Our analyses, in terms of a predetermined (1956-1960) set of price and cost conditions, have established several over-all relationships that merit mention. We did not study and, therefore, have no recommendations to make as to the extent that our results may apply outside of the framework specified for our investigations. The following represent the principal conclusions that resulted from our analyses, in terms of the four San Joaquin Valley subareas, and 1956-1960 price and cost conditions:

1. Both the highly variable costs for water and the quantities of this resource available to the farm operator at any specified price exert important, and sometimes decisive, influence on optimum resource allocation and adjustments for cotton-general crop farms in the San Joaquin Valley. Our analyses established clearly that such relationships exist <u>within</u> each of the four subareas studied, each with its own complex of natural, institutional, and economic conditions. Comparisons <u>among</u> these four subareas also demonstrate that the nature and extent of influences exerted by variable water costs and quantities available differ, and that these differences relate, in turn, to variations among the subareas in soils, climate and other resource characteristics, in economic phenomena , and in institutional factors.

2. Critical shortages of irrigation water, coupled with prices that effectively limit crop choices to cotton and other relatively high net return crops, sharply limit profit opportunities, in spite of highly favorable soil and climatic conditions (other than low rainfall). This is evident from the Westside model, using only ground water. Conversely,

adding surface water, even at the same variable costs per acre-foot as the existing ground water supplies, would permit earnings in this subarea at only slightly lower levels than in the Upper subarea.

3. Ample quantities of cheap irrigation water, on the other hand, will not maintain profits in spite of relatively unfavorable factors. This is evidenced by the low earnings ranking of the model for Central, as compared with those in the other subareas (except for Westside ground water-only).

4. Assuming that adequate quantities of water are available, variable costs for this input exercise a decisive influence on crop choices and acreage allocations regardless of soil and climate. The higher the water price, the narrower the range of alternative crops that will permit the farm operator to obtain maximum profits; about $16.50 per acre-foot, within cost and price conditions of this study, is the critical level beyond which farmers will minimize losses by leaving some land idle.

5. Cotton dominates the earnings pattern and occupies all land permitted under acreage allotments in all subareas. Except for those farmers to whom some specialty crop with comparable earnings is an available alternative, differences in cotton lint yields largely govern earnings income differentials among the four subarea models. Under conditions of this study, these cotton yields, in turn, depend largely on natural factors, primarily soil and climate.

6. Government price support and acreage allotment policies for cotton contribute importantly to the highly favorable competitive position that it occupies as a source of per-acre earnings in the San Joaquin Valley. Farmers would still find cotton their most profitable alternative in comparison with alfalfa and feed grains at prices fully 10 cents per pound of lint lower than the support levels prevailing from 1956-1960, except for the Central model.

7. If both price supports and acreage restrictions were eliminated, farmers would greatly expand cotton acreage, even if cotton lint prices dropped. It is quite possible, in light of this indication of increased production, plus the subsidies on commercial marketings at home and abroad, that prices would drop, perhaps well below 30 cents per pound for the quality grown in California.

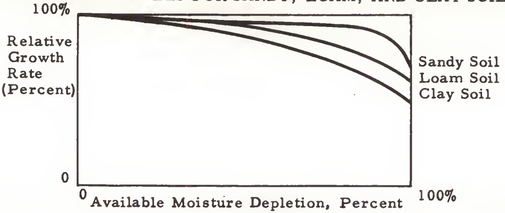
Obviously other important changes would occur to affect the relative earnings potentials of other alternative crops, in the absence of Government price support and acreage restrictions. Prices for certain of these crops, such as alfalfa and the feed grains, might rise and thus narrow the advantage that cotton has in earnings under conditions of this study. Cotton yields also might rule somewhat lower with greatly expanded acreage and subtract some more from cotton's profit margin. This study did not undertake to explore these possible developments.

APPENDIX

APPENDIX FIGURES

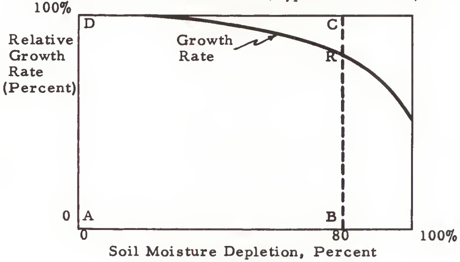
A-1

VARIATIONS IN RELATIVE GROWTH AND AVAILABLE MOISTURE DEPLETION LEVELS FOR SANDY, LOAM, AND CLAY SOILS



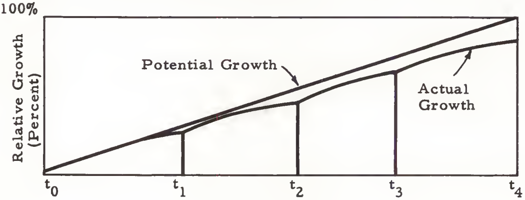
A-2

PLANT GROWTH RATES AS PERCENTAGES OF THE POTENTIAL (100 percent) AT INCREASING LEVELS OF DEPLETION FOR AVAILABLE SOIL MOISTURE (Hypothetical Data).



A-3

ACTUAL AND POTENTIAL GROWTH BY IRRIGATION CYCLES



APPENDIX TABLE A-1

Calculation Methods for Determining Annual Fixed Costs on Farm Property or Capital Goods (illustrated by 70 drawbar horsepower tracklayer tractor) a/

Noncash costs

1. Interest (6% of average investment)

$$\left[\frac{\text{Original cost + salvage value}}{2}\right] 6/100 = \left[\frac{\$17,160 + \$2,402}{2}\right] 6/100 = \$ \quad 587$$

2. Depreciation

$$\frac{\text{Original cost - salvage value}}{\text{years on farm}} = \frac{\$17,160 - \$2,402}{10} = \quad 1,476$$

TOTAL $2,063

Cash costs

1. Taxes

Assessment @ 35% of average investment = $3,423 x 6.5% levy = $ 222

2. Insurance

Estimated @ 0.75% of average investment = 73

TOTAL $ 295

ALL FIXED COSTS $2,358

a/ Fixed costs in this report include "overhead" costs that the farm operator incurs largely regardless of variations in the scope of his annual operations. A heavy proportion of these costs relate directly to land, machinery and other capital goods; some refer to such overhead as "cost of owning" such property, or, simply, as "capital costs." Another important category of fixed costs is those administrative expenses that are unavoidable in the function of managing, but that are difficult if not impossible to allocate to specific income-producing activities, or enterprises. Among this latter group are office expenses, organization dues, social security taxes, and in this study, irrigation demand charges and district assessments.

APPENDIX TABLE A-2

Irrigation Water Budget; Cotton on Hesperia Fine Sandy Loam at
100 Percent Available Soil Moisture
(all quantities in acre-inches)

Month	Root zone depth in ft.	Inches available water: per ft. of soil	Inches available water: root zone a/	New root zone in ft. b/	Evapo-trans-piration rate per day	Carry-over c/	From new root zone d/	Moisture at start of period e/	Additions f/	Total avail-able	With-drawal g/	Mois-ture at end of period	Irrigation dates
1	2	3	4	5	6	7	8	9	10	11	12	13	14
April*													
16-30	.75	1.25	.94	0	.020	0	.94	.94	0	.94	.3	.64	
May													
1-15	1.00	1.25	1.25	.25	.060	.64	.31	.95	0	.95	.9	.05	
16-31	1.50	1.25	1.87	.25	.080	.05	.62	.67	1.87	2.54	1.2	1.34	May 25
June													
1-15	2.00	1.25	2.50	.50	.167	1.34	.63	1.97	2.50	4.47	2.5	1.97	June 12
16-30	2.50	1.25	3.12	.50	.213	1.97	.62	2.59	3.12	5.71	3.2	2.51	June 28
July													
1-15	3.00	1.25	3.75	.50	.307	2.51	.63	3.14	3.75	6.89	4.6	2.29	July 10
16-31	3.33	1.25	4.16	.33	.313	2.29	.41	2.70	4.16	6.86	4.7	2.16	July 23
Aug.													
1-15	3.67	1.25	4.59	.33	.267	2.16	.41	2.57	4.59	7.16	4.0	3.16	Aug. 10
16-31	4.00	1.25	5.00	.33	.253	3.16	.41	3.57	5.00	8.57	3.8	4.77	Aug. 30
Sept.													
1-15	4.00	1.25	5.00	0	.147	4.77	--	4.77	--	4.77	2.2	2.57	--
							5.00		24.99		27.4		

* Assumes preplanting irrigation to bring soil to field capacity.
a/ Moisture available in root zone when soil is at field capacity (col. 2 x col. 3).
b/ Addition to root zone due to expansion of roots into new soil.
c/ Moisture left in root zone at end of time period (amount in col. 13 for last time period).
d/ Moisture now available to plant (col. 5 x col. 3).
e/ (col. 7 + col. 8).
f/ Moisture added to soil by irrigations to bring soil back to field capacity (col. 9 + col. 10).
g/ Evapo-transpiration rate per day times number of days in time period.

Data in columns 2, 3, 6, and 12 must be obtained from outside sources such as agronomists and irrigation personnel.

APPENDIX TABLE A-3

Estimated Field Irrigation Efficiency under Furrow Irrigation for Different Application Depths by Soil Type on Deep Well-Drained Soils

Soil type	Desired application depth in inches[a]											
	Under 2	2	2-1/2	3	3-1/2	4	4-1/2	5	5-1/2	6	7	8
	1	2	3	4	5	6	7	8	9	10	11	12
	percentages											
Fine sandy loam	35	40	45	50	55	60	63	65	65	65	65	65
Loam	50	55	60	62	64	65	66	67	68	69	70	70
Silt loam	50	55	60	62	64	65	66	67	68	69	70	70
Clay loam	50	55	58	60	63	65	65	66	67	66	63	60
Clay	60	63	65	68	65	62	60	60	58	56	54	52

a/ Assumes tail water system.

Source: Estimated by research and extension workers in irrigation problems and methods.

APPENDIX TABLE A-4

Total Water Applications by Soils, Irrigation Practices and Crops; Four Subareas
(all quantities in acre-inches)

Crop	Upper				Eastside			
	Depletion Levels for Available Soil Moisture							
	Total Water							
	1	2	3	4	1	2	3	4a/
UPPER: Hesperia F.S.L. (I) EASTSIDE: Chino C.L. (I)								
Alfalfa	76.06	76.14	76.16	--	78.01	79.87	79.96	--
Alfalfa (established)	50.28	--	--	--	55.92	--	--	--
Milo (double crop)	32.11	41.96	--	--	32.67	37.23	--	--
Milo (single crop)	38.36	48.71	36.94	--	32.53	37.27	41.37	--
Field Corn	36.10	39.32	41.05	--	35.58	43.92	37.34	--
Melons	23.05	23.86	23.86	--	30.58	35.33	--	--
Potatoes	43.75	43.36	--	60.14	--	--	--	--
Sugar Beets	45.56	47.07	48.99	--	62.58	63.48	67.08	--
Cotton	52.65	50.65	--	55.48	46.80	52.71	--	53.73
Beans	31.45	32.98	30.02	--	22.73	25.90	24.57	--
Alfalfa Seed	--	--	--	--	--	--	--	--
Cantaloup	--	--	--	--	30.58	35.33	--	--
Grain Sorghum	--	--	--	--	32.53	37.23	41.37	--
Grain Sorghum (late)	--	--	--	--	32.67	37.23	--	--
Barley	--	--	--	--	22.00	--	--	--
UPPER: Hesperia L. (I) EASTSIDE: Traver F.S.L. (II)								
Alfalfa	67.48	71.46	70.32	--	79.08	82.72	80.98	--
Alfalfa (established)	47.07	--	--	--	55.77	--	--	--
Milo (double crop)	28.53	29.10	--	--	39.41	48.34	--	--
Milo (single crop)	36.25	37.60	26.38	--	39.40	48.33	43.53	--
Field Corn	30.77	30.25	35.27	--	43.02	52.58	43.12	--
Melons	23.87	32.72	24.26	--	38.68	47.60	--	--
Potatoes	19.29	42.00	--	46.47	--	--	--	--
Sugar Beets	45.57	42.58	44.59	--	44.41	46.20	48.04	--
Cotton	40.58	46.40	--	49.07	51.29	56.18	--	67.88
Beans	20.53	24.81	21.66	--	30.60	32.51	29.92	--
Alfalfa Seed	--	--	--	--	--	--	--	--
Cantaloup	--	--	--	--	38.68	47.60	--	--
Grain Sorghum	--	--	--	--	39.40	48.33	43.53	--
Grain Sorghum (late)	--	--	--	--	39.41	48.34	--	--
Barley	22.00	--	--	--	--	--	--	--
	Westside				Central			
WESTSIDE: Panoche C.L. (I) CENTRAL: Hanford F.S.L. (I)								
Alfalfa	63.14	72.10	64.92	--	71.61	73.89	--	--
Alfalfa (established)	58.08	--	--	--	55.50	--	--	--
Milo (double crop)	39.55	39.60	--	--	46.51	47.69	--	--
Milo (single crop)	39.55	40.57	--	--	33.68	41.65	35.69	--
Field Corn	--	--	--	--	42.63	50.45	49.70	--
Melons	28.76	33.19	--	--	22.33	27.46	28.75	--
Potatoes	--	--	--	--	--	--	--	--
Sugar Beets	59.04	66.78	66.08	--	44.09	45.66	47.51	--
Cotton	41.42	48.53	--	55.26	43.78	56.63	--	69.92
Beans	23.37	26.15	--	--	30.92	33.19	--	--
Alfalfa Seed	45.10	--	--	--	--	--	--	--
Cantaloup	--	--	--	--	--	--	--	--
Grain Sorghum	--	--	--	--	--	--	--	--
Grain Sorghum (late)	--	--	--	--	--	--	--	--
Barley	--	--	--	--	--	--	--	--
WESTSIDE: Panoche S.L. (II) CENTRAL: Foster L.S. (III)								
Alfalfa	60.12	66.16	63.14	--	79.20	81.30	--	--
Alfalfa (established)	49.42	--	--	--	61.50	--	--	--
Milo (double crop)	33.21	35.25	--	--	46.80	52.41	--	--
Milo (single crop)	34.30	35.31	--	--	44.73	46.83	39.54	--
Field Corn	--	--	--	--	48.16	51.74	49.60	--
Melons	33.16	34.24	--	--	24.80	24.89	24.89	--
Potatoes	--	--	--	--	--	--	--	--
Sugar Beets	47.09	55.34	46.27	--	44.50	50.92	46.14	--
Cotton	42.83	48.57	--	53.02	52.54	55.16	--	--
Beans	21.38	25.93	22.78	--	34.14	40.59	--	--
Alfalfa Seed	50.15	--	--	--	--	--	--	--
Cantaloup	--	--	--	--	--	--	--	--
Grain Sorghum	--	--	--	--	--	--	--	--
Grain Sorghum (late)	--	--	--	--	--	--	--	--
Barley	--	--	--	--	--	--	--	--

a/ Irrigation treatments identified as: (1) 100 percent, (2) 80 percent, (3) 80-100 percent, and (4) 60 percent levels of available soil moisture depletion, respectively, prior to irrigation.

APPENDIX TABLE A-5

Variable Input Expenses and Net Returns per Acre, Summaries for All Crops, According to Soils and Irrigation Treatments a/ ; Four Subareas

Area crops by soil	a/	Preharvest costs	Harvest costs	Total variable costs	Yields	Price per unit	Gross receipts b/	Net returns	Net returns plus water cost c/
		1	2	3	4	5	6	7	8
		dollars except as noted							
UPPER SAN JOAQUIN VALLEY									
Alfalfa Hay					(tons)				
Hesperia F.S.L. d/	1	43.55	56.21	131.50	8.30	25.57	212.36	80.86	112.60
	2	44.19	57.68	134.39	8.61	25.57	220.03	85.64	118.16
Hesperia loam	1	41.25	54.93	125.10	8.03	25.57	205.39	80.29	109.21
	2	42.49	57.02	129.93	8.47	25.57	216.51	86.58	117.00
	3	42.12	55.97	128.07	8.25	25.57	210.96	82.89	112.87
Alfalfa stand									
Hesperia F.S.L.	1	42.92	31.34	95.84	4.75	25.57	121.46	25.62	47.20
Hesperia loam	1	42.22	30.58	93.48	4.59	25.57	117.37	23.89	44.57
Alfalfa 1/4 stand and 3/4 hay									
Hesperia F.S.L.	1	43.39	49.99	122.58	7.41	25.57	189.47	66.89	96.09
	2	43.87	51.10	124.76	7.64	25.57	195.35	70.59	100.38
Hesperia loam	1	41.49	48.84	117.20	7.17	25.57	183.34	66.14	93.00
	2	42.42	50.41	120.81	7.50	25.57	191.77	70.96	98.94
	3	42.14	49.62	119.43	7.34	25.57	187.68	68.25	95.91
Barley					(cwt.)				
Hesperia F.S.L.	1	33.19	10.26	51.70	28.40	2.16	61.34	9.64	17.89
Hesperia loam	1	33.19	10.83	52.27	32.20	2.16	69.55	17.28	25.53
Beans					(cwt.)				
Hesperia F.S.L.	1	46.04	35.85	93.68	16.15	8.53	137.76	44.08	55.87
	2	46.51	36.94	95.81	16.83	8.53	143.56	47.75	60.11
Hesperia loam	1	42.61	34.96	85.27	15.59	8.53	132.98	47.71	55.41
	2	43.99	36.56	89.85	16.59	8.53	141.51	51.66	60.96
	3	43.03	35.60	86.76	16.00		136.48	49.72	57.85
Cotton					(lbs.)				
Hesperia F.S.L.	1	108.13	58.56	186.43	1,425.00	.33	522.39	335.96	355.70
	2	109.80	60.39	192.17	1,485.00	.33	544.48	352.31	374.19
	4	111.40	60.70	195.78	1,495.00	.33	548.06	352.28	375.96
Hesperia loam	1	104.37	57.03	176.62	1,375.00	.33	504.06	327.44	342.66
	2	106.19	59.78	183.37	1,465.00	.33	537.06	353.69	371.09
	4	107.02	60.39	185.81	1,485.00	.33	544.39	358.58	376.98
Milo (double crop)					(cwt.)				
Hesperia F.S.L.	1	34.38	13.48	62.85	47.40	2.09	99.07	36.22	50.60
	2	37.38	13.88	69.96	49.40	2.09	103.25	33.29	51.37
Hesperia loam	1	33.74	13.16	61.10	45.80	2.09	95.72	34.62	48.21
	2	34.17	13.76	62.35	48.80	2.09	101.99	39.64	53.45
Milo (single crop)									
Hesperia F.S.L.	1	37.50	13.48	65.98	47.40	2.09	99.07	33.09	47.47
	2	40.52	13.88	73.09	49.80	2.09	103.25	30.16	48.24
Hesperia loam	1	36.86	13.16	64.22	45.80	2.09	95.72	31.50	45.09
	2	37.29	13.76	65.71	48.80	2.09	101.99	36.28	50.38
Potatoes					(cwt.)				
Hesperia F.S.L.	2	159.77	284.76	460.79	266.00	2.30	611.80	151.01	167.27
	4	161.12	289.70	473.38	272.00	2.30	625.60	152.22	174.78
Hesperia loam	2	166.25	281.82	458.57	265.00	2.30	609.50	150.93	161.43
	4	171.24	286.00	474.67	269.00	2.30	618.70	144.03	161.46
Sugar Beets					(tons)				
Hesperia loam	1	103.36	50.45	172.66	20.18	13.25	267.39	94.73	113.58
	2	103.87	53.70	177.55	21.48	13.25	284.61	107.06	127.04
SAN JOAQUIN VALLEY EASTSIDE									
Alfalfa Hay					(tons)				
Chino clay loam	1	61.53	55.21	116.74	8.09	25.57	206.86	90.12	109.64
	2	62.53	57.87	120.40	8.65	25.57	221.18	100.78	120.74
Traver F.S.L. e/	1	65.60	57.35	122.95	8.54	25.57	218.37	95.42	116.10
	2	65.79	59.06	124.85	8.90	25.57	227.57	102.72	122.49
	3	65.73	58.16	123.89	8.71	25.57	222.71	89.82	118.62
Alfalfa stand									
Chino clay loam	1	56.40	31.23	87.63	4.49	25.57	114.81	27.18	41.16
Traver F.S.L.	1	58.90	32.53	91.43	4.75	25.57	121.46	30.03	43.97
Alfalfa comb. 1/4 stand and 3/4 hay									
Chino clay loam	1	60.25	49.22	109.47	7.19	25.57	183.85	74.38	92.52
	2	61.00	51.21	112.21	7.61	25.57	194.59	82.38	100.84
Traver F.S.L.	1	63.92	51.15	115.07	7.59	25.57	194.08	79.01	98.01
	2	64.07	52.43	116.50	7.86	25.57	200.98	84.48	102.79
	3	64.03	51.75	115.78	7.72	25.57	197.40	81.62	99.96

(Continued on next page.)

Appendix Table A-5 continued.

Area crops by soil	a/	Preharvest costs	Harvest costs	Total variable costs	Yields	Price per unit	Gross receipts b/	Net returns	Net returns plus water costs c/
		1	2	3	4	5	6	7	8
		dollars except as noted							
SAN JOAQUIN VALLEY EASTSIDE (continued)									
Barley					(cwt.)				
Chino clay loam	1	38.59	10.71	49.30	31.40	2.16	67.82	18.52	24.02
Traver F.S.L.	1	38.44	10.26	48.70	28.40	2.16	61.34	12.64	18.14
Beans									
Chino clay loam	1	48.68	40.59	89.27	19.12	8.53	163.09	73.82	79.50
	2	50.47	42.64	93.11	20.40	8.53	174.01	80.90	87.38
	3	49.71	41.42	91.13	19.64	8.53	167.53	76.40	82.54
Traver F.S.L.	1	53.02	35.85	88.87	16.15	8.53	137.76	48.89	56.55
	2	54.38	36.94	91.32	16.83	8.53	143.56	52.24	60.61
Cotton					(lbs.)				
Chino clay loam	1	116.34	46.95	163.29	1,045.00	.33	383.27	219.98	231.68
	2	119.66	49.24	168.90	1,120.00	.33	410.77	241.87	255.05
	4	120.61	50.01	170.62	1,145.00	.33	419.93	249.31	262.74
Traver F.S.L.	1	118.36	44.05	162.42	950.00	.33	348.26	185.84	198.66
	2	121.16	45.27	166.43	990.00	.33	362.83	196.40	210.45
	4	125.05	45.43	170.48	995.00	.33	364.94	194.46	208.77
Field Corn					(cwt.)				
Chino clay loam	1	60.81	29.04	89.85	44.80	2.52	112.90	23.05	31.95
	2	65.45	30.40	95.85	48.00	2.52	120.96	25.11	36.09
	3	61.79	29.72	91.51	46.40	2.52	116.93	25.42	34.76
Traver F.S.L.	1	65.17	30.15	95.32	47.40	2.52	119.45	24.13	34.88
	2	71.09	31.00	101.09	49.40	2.52	124.49	23.40	36.54
Melons					(crates)				
Chino clay loam	1	121.22	351.00	472.22	180.00	3.80	684.00	211.78	219.42
	2	123.87	374.40	498.27	192.00	3.80	729.60	231.33	240.16
Traver F.S.L.	1	126.65	333.45	460.10	171.00	3.80	649.80	189.70	199.37
	2	131.63	347.10	478.73	178.00	3.80	676.40	197.67	209.57
Milo (double crop)					(cwt.)				
Chino clay loam	1	40.82	12.96	53.78	44.80	2.09	93.63	39.85	48.02
	2	43.34	13.60	56.94	48.00	2.09	100.32	43.38	52.69
Traver F.S.L.	1	50.85	13.48	64.33	47.40	2.09	99.07	34.74	44.59
	2	55.81	13.88	69.69	49.40	2.09	103.25	33.56	45.64
Milo (single crop)									
Chino clay loam	1	44.86	12.96	57.82	44.80	2.09	93.63	35.81	43.94
	2	46.32	13.60	59.92	48.00	2.09	100.32	40.40	49.64
Traver F.S.L.	1	54.01	13.48	67.49	47.40	2.09	99.07	31.58	41.43
	2	58.98	13.88	72.86	49.40	2.09	103.25	30.39	42.47
	3	56.30	13.68	69.98	48.40	2.09	101.16	31.18	42.06
Sugar Beets					(tons)				
Chino clay loam	1	127.01	56.16	183.17	21.60	13.25	286.20	103.03	118.67
	2	127.52	60.06	187.58	23.10	13.25	306.08	118.50	134.36
SAN JOAQUIN VALLEY WESTSIDE									
Alfalfa hay					(tons)				
Panoche clay loam I	1	26.22	59.53	135.63	9.00	25.57	230.13	94.50	144.38
	2	28.84	62.38	148.18	9.60	25.57	245.47	97.29	154.25
	3	26.73	60.96	138.98	9.30	25.57	237.80	98.82	150.11
Panoche loam II	1	25.31	51.65	124.45	7.34	25.57	187.68	63.23	110.72
	2	27.11	53.88	133.26	7.81	25.57	199.70	66.44	118.71
	3	26.19	52.98	129.05	7.62	25.57	194.84	65.79	115.67
Alfalfa stand									
Panoche clay loam I	1	31.68	30.10	107.66	4.49	25.57	144.81	7.15	53.03
Panoche loam II	1	29.13	27.77	95.94	4.00	25.57	102.28	6.34	45.38
Alfalfa 1/4 stand and 3/4 hay									
Panoche clay loam I	1	27.58	52.17	128.64	7.87	25.57	201.24	72.60	121.48
	2	29.55	54.31	138.05	8.32	25.57	212.74	74.69	128.88
	3	27.97	53.24	131.15	8.10	25.57	207.12	75.97	125.91
Panoche loam II	1	26.26	45.68	117.33	6.51	25.57	166.46	49.13	94.51
	2	27.62	47.35	123.93	6.86	25.57	175.41	51.48	100.44
	3	26.92	46.68	120.77	6.72	25.57	171.83	51.06	98.23

(Continued on next page.)

Appendix Table A-5 continued.

Area crops by soil	a/	Preharvest costs	Harvest costs	Total variable costs	Yields	Price per unit	Gross receipts b/	Net returns	Net returns plus water cost c/
		1	2	3	4	5	6	7	8
		dollars except as noted							
SAN JOAQUIN VALLEY WESTSIDE (continued)									
Alfalfa seed					(lbs.)				
Panoche clay loam I	1	67.90	32.13	135.66	504.00	.29	151.10	15.44	51.07
Panoche loam II	1	69.40	32.13	141.15	504.00	.29	151.10	9.95	49.57
Alfalfa seed stand									
Panoche clay loam I	1	96.68	32.13	151.15	504.00	.29	151.10	- 0.05	22.29
Panoche loam II	1	99.56	32.13	157.62	504.00	.29	151.10	- 6.52	19.41
Alfalfa seed 1/3 stand and 2/3 seed									
Panoche clay loam I	1	77.40	32.13	140.77	504.00	.29	151.10	10.33	41.57
Panoche loam II	1	79.35	32.13	146.58	504.00	.29	151.10	4.52	39.62
Barley					(cwt.)				
Panoche clay loam I	1	28.72	11.40	57.53	36.00	2.16	77.76	20.23	37.64
Panoche loam II	1	28.72	11.52	57.65	36.80	2.16	79.49	21.84	39.25
Beans									
Panoche clay loam I	1	43.56	38.80	100.82	18.00	8.53	153.54	52.72	71.18
	2	44.42	40.72	105.80	19.20	8.53	163.78	57.98	78.64
Panoche loam II	1	42.95	36.41	96.25	16.50	8.53	140.75	44.50	61.39
	2	44.34	38.16	102.98	17.60	8.53	150.13	47.15	67.63
Cotton					(lbs.)				
Panoche clay loam I	1	106.13	51.51	190.36	1,349.84	.33	495.01	304.65	337.31
	2	108.32	54.26	200.92	1,439.83	.33	527.89	326.97	365.31
	4	110.41	55.33	209.40	1,474.82	.33	540.80	331.40	375.06
Panoche loam II	1	106.55	45.25	185.64	1,144.86	.33	419.63	233.99	267.83
	2	108.34	47.54	194.25	1,219.85	.33	447.11	252.86	291.23
	4	109.95	48.00	199.64	1,234.85	.33	452.52	252.88	294.77
Melons					(crates)				
Panoche clay loam I	1	113.21	351.00	486.97	180.00	3.80	684.00	197.03	219.79
	2	114.56	374.40	515.18	192.00	3.80	729.60	214.42	240.64
Panoche loam II	1	114.55	333.45	474.20	171.00	3.80	649.80	175.60	201.80
	2	114.88	347.10	489.03	178.00	3.80	676.40	187.37	214.42
Milo (double crop)					(cwt.)				
Panoche clay loam I	1	37.57	12.96	81.77	44.80	2.09	93.63	11.86	43.10
	2	37.58	13.60	82.46	48.00	2.09	100.32	17.86	49.14
Panoche loam II	1	35.63	13.16	75.03	45.80	2.09	95.72	20.69	46.93
	2	36.25	13.76	77.86	48.80	2.09	101.99	24.13	51.98
Milo (single crop)									
Panoche clay loam I	1	39.83	12.96	84.03	44.80	2.09	93.63	9.60	40.84
	2	40.14	13.60	85.79	48.00	2.09	100.32	14.53	46.58
Panoche loam II	1	38.15	13.16	78.41	45.80	2.09	95.72	17.31	44.41
	2	38.31	13.76	79.96	48.80	2.09	101.99	22.03	49.92
Sugar Beets					(tons)				
Panoche clay loam I	1	102.85	49.45	198.94	19.78	13.25	262.09	63.15	109.79
	2	105.17	52.88	210.84	21.15	13.25	280.24	69.40	122.16
	3	105.11	52.08	209.39	20.83	13.25	276.00	66.61	118.81
Panoche loam II	1	99.26	40.15	176.61	16.06	13.25	217.80	36.19	73.39
	2	101.17	42.53	187.42	17.01	13.25	225.38	37.96	81.68
CENTRAL SAN JOAQUIN VALLEY									
Alfalfa hay									
Hanford F.S.L.	1	39.30	18.01	65.46	3.80	25.57	97.17	31.71	39.86
Hanford F.S.L. (alkali)	1	39.30	16.08	63.53	2.85	25.57	72.87	9.34	17.49
Foster loam	1	40.73	18.01	67.72	3.81	25.57	97.42	29.70	38.68
Alfalfa stand									
Hanford F.S.L.	1	35.21	35.41	81.08	7.60	25.57	194.33	113.25	123.71
	2	35.74	36.05	82.58	7.90	25.57	202.00	119.42	130.21
Hanford F.S.L. (alkali)	1	34.91	33.41	78.78	6.65	25.57	170.04	91.26	101.72
	2	35.74	33.94	80.47	6.90	25.57	176.43	95.96	106.75
Foster loam	1	37.09	35.46	84.11	7.62	25.57	194.84	110.73	122.29
	2	37.59	36.08	85.54	7.92	25.57	202.51	116.97	128.84
Alfalfa 1/3 stand and 2/3 hay									
Hanford F.S.L.	1	36.56	29.67	75.88	6.33	25.57	161.86	85.98	95.67
	2	36.91	30.10	76.88	6.53	25.57	166.97	90.09	100.00
Hanford F.S.L. (alkali)	1	36.36	27.69	73.70	5.38	25.57	137.67	63.97	73.66
	2	36.56	28.05	74.83	5.53	25.57	141.40	66.57	76.48
Foster loam	1	38.29	29.70	78.65	6.35	25.57	162.37	83.72	94.42
	2	38.63	30.12	79.60	6.55	25.57	167.48	87.88	98.78

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Appendix Table A-5 continued.

Area crops by soil	a/	Preharvest costs	Harvest costs	Total variable costs	Yields	Price per unit	Gross receipts b/	Net returns	Net returns plus water costs c/
		1	2	3	4	5	6	7	8
		dollars except as noted							
CENTRAL SAN JOAQUIN VALLEY (continued)									
Barley					(cwt.)				
Hanford F.S.L.	1	27.89	10.27	41.51	28.50	2.16	61.56	20.95	23.40
Hanford F.S.L. (alkali)	1	27.89	10.27	41.51	28.50	2.16	61.56	20.95	23.40
Foster loam	1	27.89	8.90	40.14	19.00	2.16	41.04	.90	4.25
Beans									
Hanford F.S.L.	1	42.54	32.72	79.77	14.20	8.53	121.13	41.36	45.87
	2	43.12	33.68	81.65	14.80	8.53	126.24	44.59	49.44
Hanford F.S.L. (alkali)	1	42.54	32.72	79.77	14.20	8.53	121.13	41.36	45.87
	2	43.12	33.68	81.65	14.80	8.53	126.24	44.59	49.44
Foster loam	1	44.38	34.32	83.68	15.20	8.53	129.66	45.98	50.96
	2	45.01	35.28	86.22	15.80	8.53	134.77	48.55	54.48
Cotton					(lbs.)				
Hanford F.S.L.	1	104.67	40.39	151.45	823.00	.33	302.24	150.79	157.18
	2	107.14	41.46	156.87	857.00	.33	314.83	157.96	166.23
	4	109.55	41.76	161.52	867.00	.33	318.59	157.07	167.28
Hanford F.S.L. (alkali)	1	104.67	36.72	147.78	704.00	.33	258.39	110.61	117.00
	2	107.14	37.64	153.05	733.00	.33	269.33	116.28	124.55
	4	109.55	37.95	157.71	743.00	.33	273.09	115.38	125.59
Foster loam	1	105.15	33.21	146.03	590.00	.33	216.66	70.63	78.30
	2	105.63	33.97	147.65	614.00	.33	225.49	77.84	85.89
	4	108.41	34.13	152.25	619.00	.33	227.61	75.36	85.07
Field Corn					(cwt.)				
Hanford F.S.L.	1	46.64	30.19	83.05	47.50	2.52	119.70	36.65	42.87
	2	48.91	30.87	87.15	49.45	2.52	124.61	37.46	44.83
Hanford F.S.L. (alkali)	1	46.64	26.15	79.01	38.00	2.52	95.76	16.75	22.97
	2	48.91	26.79	83.07	39.50	2.52	99.54	16.47	23.84
Foster loam	1	48.05	22.15	77.23	28.60	2.52	72.07	- 5.16	1.87
	2	48.96	22.63	79.14	29.70	2.52	74.84	- 4.30	3.25
Milo (double crop)									
Hanford F.S.L.	1	34.51	11.70	53.00	38.00	2.09	79.42	26.42	33.21
	2	34.84	11.93	53.73	39.50	2.09	82.56	28.83	35.79
Hanford F.S.L. (alkali)	1	34.51	11.70	53.00	38.00	2.09	79.42	26.42	33.21
	2	34.84	11.93	53.73	39.50	2.09	82.56	28.83	35.79
Foster loam	1	34.58	9.57	50.98	23.80	2.09	49.74	- 1.24	5.59
	2	36.00	9.71	53.36	24.75	2.09	51.73	- 1.63	6.02
Milo (single crop)									
Hanford F.S.L.	1	33.39	11.70	50.01	38.00	2.09	79.42	29.41	34.33
	2	35.44	11.93	53.45	39.50	2.09	82.56	29.11	35.19
Hanford F.S.L. (alkali)	1	33.39	11.70	50.01	38.00	2.09	79.42	29.41	34.33
	2	35.44	11.93	53.45	39.50	2.09	82.56	29.11	35.19
Foster loam	1	36.20	9.57	52.30	23.80	2.09	49.74	- 2.56	3.97
	2	36.76	9.71	53.31	24.74	2.09	51.73	- 1.58	5.26

a/ Irrigation treatments identified as (1) 100, (2) 80, (3) 80-100, and (4) 60 percent levels of available soil moisture depletion, respectively, prior to irrigation.

b/ Includes value of cotton seed.

c/ Net returns under a zero charge for water variable expenses.

d/ Hesperia fine sandy loam.

e/ Traver fine sandy loam.